A COMPARATIVE STUDY OF NATIVE AND PAKISTANI GEOLOGY RESEARCH ARTICLES

by

MUJIB RAHMAN

PhD

Doctor of Philosophy

The University of Edinburgh

1995

ABSTRACT

Working within the framework of genre analysis and systemic linguistics, this thesis presents a comparative analysis of published native and Pakistani geology experimental research articles (RAs) with a view to examining differences in the Pakistani geologists' scientific reporting *vis-a-vis* their native counterparts': differences in discourse organisation (genre), thematic choices (thematic configuration), the method of development, and the use of interpersonal (mood/ modality, attitudinal adjuncts, etc.) and textual rhetoric (discourse adjuncts, metalinguistic comments, etc.). Also, a Three-Move rhetorical model is developed and proposed for the RA discussion section which is then used to compare the two datasets, each consisting of thirty research articles written by native and Pakistani academic geoscientists. Experimental RAs were used in the study for three very apparent reasons: (i) it is unquestionably the greatest exemplar of 'information exchange' in the world of science, bearing the full thrust of a discourse community's epistemic objectives; (ii) it has an established generic and discourse structure; and (iii) it has one globally acknowledged intention, that of persuading other scientists to consider and accept the truth and the worth of the author's research. All this makes the experimental RAs amenable to all kind of textual, discourse, and rhetorical analyses. The theoretical frameworks used in the study proved not only productive but also illuminating. In fact, the framework of *rhetorical prosodies* (interpersonal & textual rhetoric) was unique to this study. In this respect, and in all other respects, the Pakistani RAs exhibited obvious and subtle differences. Following are the most important findings: (1) The Pakistani geologists did not give as much importance to the crucial Swalesian Move-2 (*Establishing the niche*) as their native counterparts; (2) the Pakistani geologists used longer introductory Moves in both the introduction and the discussion sections; (3) the Pakistani discussions had a shorter Move 2 (*Discussing the findings*) and a shorter Move 3 (*Generalising the findings*); (4) the Pakistani scientists used fewer interpersonal and textual points of departure than their native counterparts; (5) the Pakistani geologist had problems with chaining topical themes, crucial for having a uniform focus and a consistent method of development; (6) the Pakistani writers also used fewer interpersonal prosodies, and fewer First Person pronouns, though they used more modal expressions (hedges). As all the differences were found to be statistically significant, the main conclusion drawn from this study is that the Pakistani writers are more tentative and less assertive in their claims. Another distinctive feature of this study was the use of actual records of native referees' comments on Pakistani manuscripts submitted to international journals. The native referees' comments corroborate the findings reported in the study. Finally, a series of workshops are proposed to address the problems identified in the course of this study. Directions for further research are also pointed out.◆

ACKNOWLEDGEMENTS

I should like to thank Dr. Gibson Ferguson, my supervisor, for helping me in my research programme throughout. My gratitude also goes to Miss Jean Ure for clarifying certain aspects of the systemic approach. However, as it stands, the interpretation of the approach is entirely my own.

I am most grateful to the Association of Commonwealth Universities and the Commonwealth Scholarship Commission in the UK for sponsoring my research programme at the University of Edinburgh, and to the University of Peshawar and the Ministry of Education, Islamabad, Pakistan, for nominating me for the award.

My sincere gratitude goes to my geologist friends at the University of Peshawar for giving me their manuscripts along with comments from their native referees/editors, and for having no qualms about their work being discussed in this thesis at such great length.

Finally, I should like to thank my wife, Durre, and my daughter, Saima, for their support and tolerance throughout, and for not complaining about being kept away from their kindred so long; to our little one, Saman, who kept us happy, first, with her gurgles and, then, with her frolics and romps; and to the wee one, Farzeen, the newborn, for restarting the cycle. To them, and to my parents and all our kindred, I dedicate this work!♥

A man's reach should exceed his grasp,
Or what's a Heaven for?

Robert Browning:
Andrea del Sarto (1855)

DECLARATION

I solemnly declare that this thesis, from inception to finish, is entirely of my own execution, that no one can make any claim to any part of it, and that every primary, or secondary, source of knowledge referred to in these pages has been acknowledged.◆

CONTENTS

List of Appendices

List of Tables

List of Figures

CHAPTER 1

Introduction

1.1 Background and Purpose

It is a well known fact that there is a dearth of scientific research reporting and dissemination in international journals from non-Anglophone countries, particularly from the Third World (Swales, 1985; see Swales, 1990, Chapter 6, for a review). Even countries with a strong tradition of using English as the language of scientific scholarship because of their colonial history, like Pakistan and India, appear not to be contributing much to the pool of scientific knowledge (Swales, 1985). And most of the non-native research that gets published in international journals comes from non-native researchers based in anglophone institutions. The competition is getting tougher by the day because of the increase in research production, a perceptible concomitant of advancement in computer, communication, and other related technologies. This competition becomes all the tougher for the non-native scientists from the Third World countries as they may be working in conditions lacking in even basic facilities that are usually taken for granted by scientists in advanced countries. And with journal rejection rates on the increase constantly, the " pressure on manuscripts that betray evidence of non-standard English" (Swales, 1990:103) is on the increase, too. For the non-native scientists, communicating in English may be the heaviest burden of all burdens as communicating effectively in English does not mean to get only the syntax right. Also, there are other dimensions to communicating in English, particularly to communicating science in English, such as complying with the norms and conventions of written English discourse as well as to those of scientific reporting.

It has been shown that non-native writing differs from native writing on two accounts:

grammatical differences and discourse differences. While the first might cause a breakdown in meaning, the second, which is more serious, could lead to difficulties in understanding the writer's intention as a whole. Discourse based differences have been attributed to 'cultural rhetorical patterns' (Kaplan, 1966, 1987). This attribution is based on the assumption that people from different cultural backgrounds have " different stylistic habits, [and] different ways of thinking" (Harder, 1984:115). This signifies that various cultures would not only " organize the development of ideas differently" (Ostler, 1987:169) but also " would orient their discourse in different ways" (Leki, 1991:124). But it has not been shown hitherto whether these differences are really due to cultural effect or whether they are simply due to developmental factors in learning the language (Mohan and Lo, 1985). Since this point is discussed in detail in the next chapter, we need not labour the point any further. It suffices to say that English texts written by non-native speakers of English (NNSE) are likely to be different from those written by native speakers of English (NSE). If such differences are found to hinder communication or impair its effectiveness in any way, they must be addressed and remedied: a scientist cannot afford to be misunderstood or misinterpreted. As such, in order to be able to write a piece of research acceptable for publication, the scientist writer must have a knowledge of the following features of the research article:

> 1. the conventional pattern of organisation found in a research article; i.e., sections such as Introduction, Method, Results, Discussion, as well as, an Abstract section [***formal schemata***].
> 2. the purpose and content of each section; e.g., the Introduction should have a review of the past literature and a statement of purpose [***genre conventions***].
> 3. the possible choices of lexis and structure conventionally used to express each 'move' used in different sections [***discourse conventions and signalling***].
> 4. a background knowledge of the specialised content area [***content schemata***].
>
> *[Jingfu, 1987:81]*

The writer of a research article, whether native or non-native speaker of English, must already possess the fourth precondition, but may lack at least one of the other three (*op cit.*:81-82). It is a well-known fact that:

> Specialist writers seem to be fairly consistent in the way they organize their overall message in a particular genre, and analysis of structural organization of the genre reveals preferred ways of communicating intention in specific areas of inquiry.
> *[Bhatia, 1993:29]*

The realisation of this fact has been instrumental in engendering interest in macro-textual, or genre-based, investigation of scientific research articles. This concern with the macro-features of texts gained impetus with the publication of Swales' (1981) 4-Move genre pattern for the scientific RA introduction. Quite a few studies have appeared since then, dealing with grammatical, lexical, organisational and rhetorical features of the RA in various science fields and disciplines. Several researchers (Lopez, 1982; Bley-Vroman & Selinker, 1984; Crookes, 1986: Cooper, 1985; Jacoby, 1986; Jingfu, 1987; Hughes, 1989; Dudley-Evans and Henderson, 1990) have attempted to apply this model to scientific RA introductions in a number of disciplines, such as agricultural & chemical engineering, biology, chemistry, computer science, economics, electronics, physics, medical sciences, and the social sciences. Writing introductions has always been troublesome, even for the native speaker of English academics (Swales 1990:137), and, *a fortiori*, more so for the non-native speaker of English. A study by Hopkins and Dudley-Evans (1988) shows that the RA discussion section is also analysable on the same lines as the introduction section. However, the schematic model proposed by them needs validation as well as refinement. Moreover, there are very few studies dealing with non-native RAs. More scarce are studies that attempt a contrastive study of NSE and NNSE RAs. Therefore, there is a pressing need for a detailed contrastive study of the kind proposed here.

The study reported in these pages is an exercise in contrastive text linguistics and text analysis of published scientific research articles (RAs) in English written by native speakers of English (NSE) and Pakistani geologists (NNSE). The study comprises genre analysis of RA sections (introduction and discussion), theme choice and theme development analysis, an analysis of rhetorical prosodies[1] and that of referees' comments on Pakistani research articles submitted to international journals. The study is motivated by a concern for the problems and difficulties faced by Pakistani geologists and scientists in writing research articles. Many never attempt to write for an international journal; hence, such publications are extremely rare. I concur, in

[1] This term I use to refer collectively to *interpersonal* elements and *textual* devices that perform the function of interacting with the reader, facilitating the reading process (*metalinguistic comments*), and evincing the writer's attitude towards and his commitment to the value or status of his propositions and statements. See section 3.3.5 for a discussion.

principle, with Frankenberg-Garcia (1990a,b) that skilled L2 writers also need support. This need derives from the fact that it is the skilled writers who need to publish their work in English to reach a wider audience. Hence, they must make their work conform to the international norms of scientific inquiry. Since these writers already possess linguistic competence and have acquired the generic conventions of their discourse community, they only need instruction in order to improve their knowledge of the rhetorical and discourse conventions of the target language. Hence a detailed programme of seminars and workshops is also proposed to overcome the problems identified in the course of this study.

1.2 Need for the Study

Although the need for the present study grew out of practical concerns, its immediate purpose is to contribute to the field of written text analysis. Although, for operational reasons, only geology RAs have been selected for the study, the results should have comparable implications for other science disciplines, such as biology, chemistry, physics, medicine, etc., since scientific text, especially the research article, is a highly standardised class of text that is almost universal. " Technical discourse," according to Meyer (1987:8) " is not just one type of discourse among many others. It is the prototype of coherent discourse...." Hence, a study of scientific RAs is not only desirable but also highly profitable. Such theoretical studies should be undertaken if the field is to be developed further.

Since the research articles are the principal source of knowledge and the primary domains of scientific exchange in the academic scientific world, they are important for specialists and learners alike. And a study that seeks to examine scientific RAs will be of interest to both the specialists and the non-specialist teachers who are engaged in teaching in the field of English for Specific and Technical purposes. It is highly desirable to arrange seminars and workshops for non-native specialists to help them become much more aware of the demands of RA writing. But before one could even think of arranging such workshops and seminars, one needs to be armed with a sound knowledge of the genre, and other discourse features that go with it. One must also have some cognisance of the problems that the prospective participants face when writing research articles. The very fact that the RA genre has established features makes it amenable to all kind of analyses with respectable certainty that the problems discovered are really problematic.

Experimental RAs usually consist of sections that signal the development of the reported experiment. This organisation is referred to as rhetorical structure, schematic structure, or genre structure. It has been proposed that the logical rhetorical organisation of the RA usually has four functional divisions: Introduction, Method, Results, and Discussion (IMRD). However, two main variations have been reported: a) some writers subsume the Method and the Results sections in one, Method and Results; b) while others subsume the Results and the Discussion sections in one, Results and Discussion. In addition, a large number of RAs have an additional section, often titled Conclusion, which may sometimes be part of the Discussion section often titled Discussion and Conclusion. Whatever the combination, these functional divisions are invariably found in the research article, not only within a discipline but across a range of scientific disciplines. However, this rhetorical structure is more manifest in experimental scientific RAs than, say, in papers of a theoretical nature (see Figure 1 below; also see Chapter 2 for details).

1.3 Addressing the Need

Though this study was originally prompted by Genre Analysis and my earlier attempt (Rahman, 1991) to test the ***CARS*** model (Swales, 1990) for RA introductions, I now intend to adopt a combination of approaches to illuminate the various facets of the study. As already mentioned in the beginning, this is a comparative study of native and non-native (Pakistani) RAs. And in any kind of comparative study, it is absolutely essential to adopt an approach that proves not only feasible but also illuminating. As Ravelli (1988) notes:

> there are many things we *can* mean, and in order to communicate we *choose* from this range of potential meanings. Therefore a theory of language must be able to describe both the potential, and the instantiation of a choice from that potential.
>
> *[Ravelli, 1988:133]*

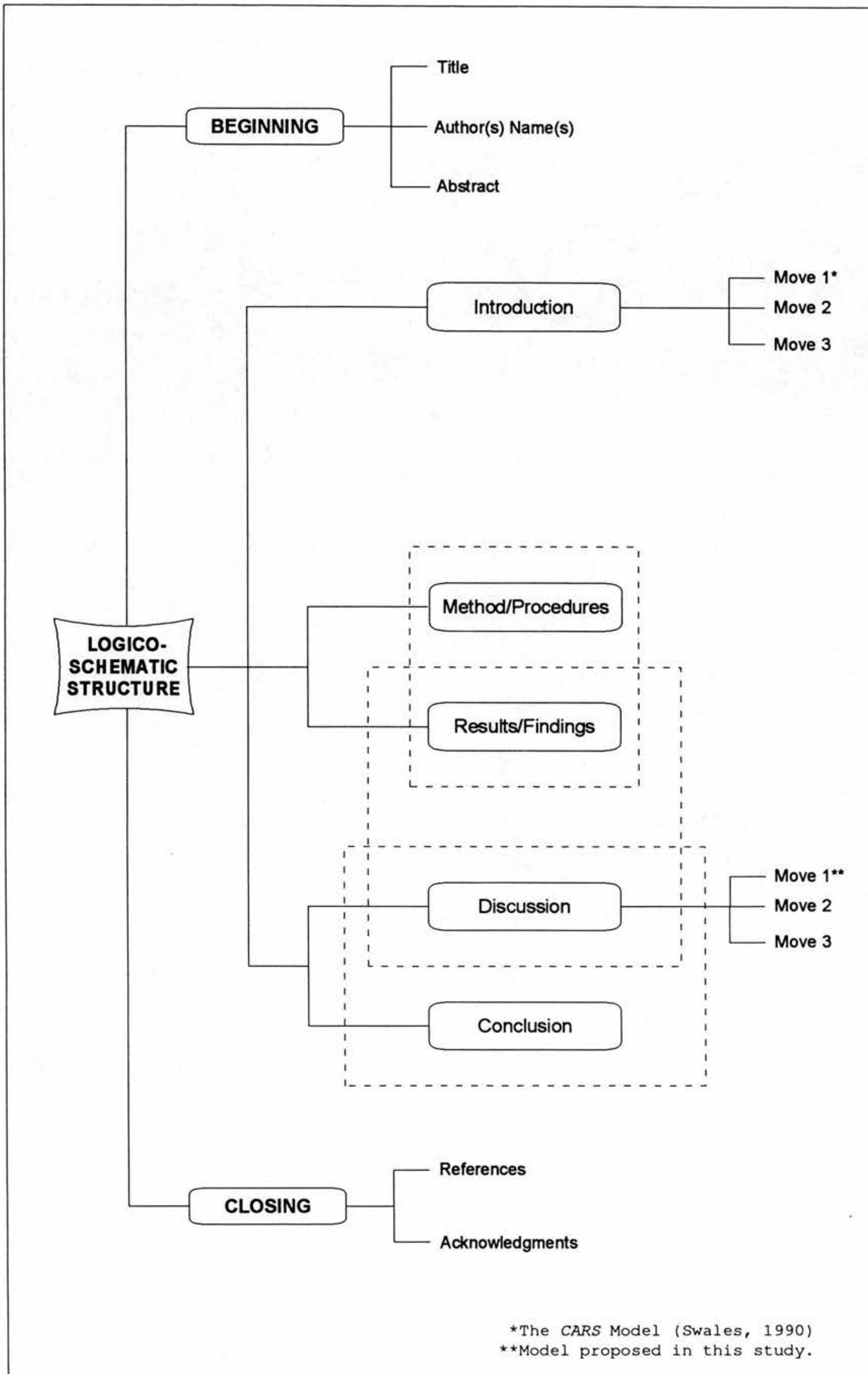

Figure 1: Informational/Rhetorical Structure of the Experimental Research Article

However, there is not one such approach that would serve the purpose of this study and be also feasible and illuminating at the same time; hence, the need to adopt a combination of approaches to fulfil the aims of the study.

Text structure involves a number of things: there are semantic as well as structural aspects to texts. And there are direct (*Note that ...; The reader should note ...;*) as well as indirect (*It should be noted ...*) ways of addressing the reader. Also the amount of information included in a text reveals a writer's assumptions about his readers. While some of these assumptions are rooted in the socio-culture of a speech community, others can be traced to the discourse-culture of a discourse community (see Chapter 2 for a discussion of this term). Based on these considerations, an applied procedure for genre analysis is proposed in Chapter 3 which is based on Martin's (1985) three semiotic planes (as will be discussed in Chapter 2).

Genre analysis is very important for the development of EAP courses, as it has the potential to be used to define genres that the students and the writing instructor encounter in their courses. If these genres are described adequately, the instructor will not have to worry about discipline specific knowledge. As such, genre analysis is:

> (...) the most promising analytical framework which reveals not only [*sic.*] the utilizable form-function correlations but also contributes significantly to our understanding of the cognitive structuring of information in specific areas of language use, which may help the ESP practitioner to devise appropriate activities potentially significant for the achievement of desired communicative outcomes in specialized academic or occupational areas.
>
> *[Bhatia, 1991:154]*

As such, for the study of discourse organisation, two approaches have been adopted here: first, following Swales' (1981; 1990) ***genre analysis***, the RA introductions and discussions are examined for the schematic organisation of information in rhetorical units often termed as ***Moves*** (Chapters 4 & 5) which results in a model for the discussion section (Chapter 5); second, following Halliday's (1985) systemic-functional model, the texts are analysed for ***theme types*** and ***method of development*** (Chapter 6). The texts are further analysed for the ***rhetorical prosodies***

(Chapter 7). The systemic functional model is adopted here, for it is the only model that

> [...] does provide a way of studying text which helps us to understand how meanings are expressed. It gives us insight into generalities of meaning: language that signifies a particular relationship between the [writer] and the [reader]: language that signifies a particular event or feeling in the [writer's] world of experience; and language that signifies a particular textual organization of these meanings. It also gives us insight into the specifics of realization: how choices in meaning are reflected in, and conveyed by, the lexicogrammar, and organized over a whole text.
>
> *[Ravelli, 1988:133]*

In addition to text organisation analysis, the comments made by native referees and editors on Pakistani RAs submitted to international journals are also examined (Chapter 8) to substantiate the findings from studies reported in Chapters 4 to 7, and underpin major areas of difficulty that may cause rejection of the papers. For this purpose, my colleagues at the Department of Geology, University of Peshawar were kind enough to provide me with draft copies of their RAs along with copies of reviewers' comments. Chapter 9 deals with suggestions in order to overcome the problems as identified in the study.

The purpose of this study, therefore, is to discover how different are the native and the Pakistani RAs in terms of genre structure, thematic choice (in terms of Halliday's metafunctions), thematic progression, and rhetorical prosodies; to underpin problems of expression and communication in the Pakistani RAs, and to provide pedagogical recommendations.

1.4 The Research Questions

As already outlined above, this study seeks to investigate discourse level problems and differences in published research articles written by Pakistani geologists by comparing them with native research articles. As such, this study seeks to answer the following research questions:

Genre Analysis

1. Do the geology experimental research articles, in general, conform to the IMRD structure which is claimed to be the logical structure of the scientific RAs? Do the native (NSE) and the Pakistani RAs differ in this respect? And if yes, are the differences statistically significant? (Chapter 4).

2. Do the geology RA introductions conform to the rhetorical structure as suggested in the ***CARS*** model (Swales, 1990)? And do the NSE and the Pakistani RA introductions differ in the employment and order of moves as proposed in the model? If yes, are the differences statistically significant? (Chapter 4).

3. Do the geology RA discussions have a rhetorical structure that can be developed into a model? Do both the NSE and the Pakistani RA discussions conform to such a model, or are there statistically significant differences? (Chapter 5).

4. If the Pakistani RAs are found to differ from the NSE RAs (in relative weighting given to a certain move) or deviate from the models (in terms of absence of a move), and if such differences and deviations are found to be statistically significant, does it have any adverse effect on the chances of their being accepted by an international journal?

Theme Choice and Method of Development

5. Are the Pakistani RAs any different from the NSE RAs in their theme choice and method of development? If yes, are the differences statistically significant? (Chapter 6).

Rhetorical Prosodies

6. Do the Pakistani RAs differ from the NSE RAs in terms of the rhetorical prosodies (interpersonal and textual elements, e.g., metalinguistic comments) as evidenced in the texts? If yes, are the differences statistically significant? (Chapter 7).

General: Corroboration and Implications

7. What is the nature of the native referees' comments made on Pakistani manuscripts submitted for international publication? Do they support, in any way, the findings reported in Chapters 4-7? (Chapter 8).

8. Do the referees' comments on Pakistani manuscripts pin-point any major areas of concern that need to be addressed? If yes, what teaching implications can be drawn from them and the major findings reported in the study? (Chapter 9).

1.5 Design of the Study

This study comprises ten chapters. Chapters 4 to 9, the main chapters, typically have the following structure:

Introduction
Method of Analysis
Findings and Discussion
Summary/Conclusion

Since the study uses both qualitative and quantitative procedures, the results are discussed with examples from the two datasets.

1.6 Outline of Chapter Content

Chapter 2 is a review of all those aspects of literature which have either general or specific relevance to the study undertaken in this thesis. The relevant background topics include genre, register, schemata, rhetoric, culture, discourse analysis, contrastive discourse analysis, and scientific discourse. The topics which have specific relevance to the study include genre analysis, the experimental research article, and systemic linguistics. The aim throughout is to draw insights that would prove useful in our present endeavours.

Chapter 3 presents an account of the general issues that underlie the methodology and frameworks adopted in this study. The chapter includes a discussion of the selection process of data (research articles) for the study, analytical procedures, and a detailed description of the theoretical frameworks adopted in the study which are then applied to the two datasets in Chapters 4 to 7.

Chapter 4 is concerned with the rhetorical organisation of the RA introduction section. For this study, the *CARS* model as proposed by Swales (1990) is used. The two datasets are compared for every possible feature. Based on the findings, a few changes in the *CARS* model are proposed.

Chapter 5 is concerned with the rhetorical organisation of the discussion section. As no viable model existed for the rhetorical organisation of the discussion section, I adopted a bottom-up approach. First, by studying the discussion sections in the two datasets (sixty in all), a three-move model is proposed for the discussion section. The model is then used to compare the two datasets for differences and variations.

Chapter 6 compares the discussion sections from the two datasets for thematic choice, and method of development. The frameworks adopted are those of Halliday (1985) and Fries (1981). First, an outline of the frameworks is presented, followed by their application. Finally, the findings are discussed along with important implications.

Chapter 7 examines the discussion sections from the two datasets for variation in the use of rhetorical prosodies. Rhetorical prosodies is an umbrella term that I use for interpersonal (mood/modality, attitudinal adjuncts, etc.) and textual rhetoric (discourse adjuncts, metalinguistic comments, etc.).

Chapter 8 analyses native referees' comments on Pakistani manuscripts submitted to international journals for possible publication. An attempt is made to relate the comments to the findings reported in the preceding chapters. The main purpose of the chapter is to corroborate (or disprove) the findings arrived at through extensive analyses.

Chapter 9 is concerned with how the problems so far identified could be remedied. A comprehensive series of workshops and seminars is proposed for tackling the problems and raising awareness among the Pakistani geologists.

Chapter 10 summarises all the important findings, discusses their important implications, and points out directions for further research.◆

CHAPTER 2

Literature Review

2.0 Introduction

In Chapter 1, the paradigms underlying this study were described and discussed in detail. It was pointed out that this study aimed to analyse research article introductions and discussions written by native speakers of English and Pakistani geologists to discover the rhetorical organisation of the geology RA. It was also pointed out that the introduction and discussion sections from the two datasets will be compared for variation in rhetorical structure, theme types, method of development, and rhetorical prosodies. On the whole, the study attempts to discover major variations in the two Pakistani RA sections that may lead to a rejection of Pakistani RA manuscripts by international journals.

This Chapter introduces and discusses the approaches that are available for the analysis of scientific or technical English in order to situate the present study within the overall current framework of discourse and genre analysis. To achieve this objective, the discussion in this chapter focuses on the concept of genre, rhetoric, schemata, contrastive rhetoric, and genre analysis along with other approaches to the analysis of scientific discourse and the research article; structuring of information in RA discussions; the concept of theme (and rheme) as expounded in the *systemic-functional approach*, and the function of interpersonal meanings in texts. Other approaches to the characterisation of theme, such as the *functional-sentence perspective* are also reviewed. The study being contrastive, problems with other contrastive studies have been pointed out. No attempt, however, is made to present the frameworks adopted for the present study. That is the concern of Chapter 3.

2.1 Text as Genre

2.1.1 The Origin and Notion of Genre

The word *genre* comes from French (and ultimately Latin, *genus*) meaning 'kind' or 'class'. It is a well-established and well-understood term in literary criticism where it is used to refer to the three main divisions of literature, the three genres being poetry, drama and prose. The function of poetics from Aristotle onwards has been to classify literature on the basis of this tripartite division. Such literary classifications have been attempted from theoretical, structural and historical perspectives (for example, Frye 1957; and Todorov 1971). Thus, "the notion of genre", as Colie (1973:2) remarks, "is historically significant." The term has recently been adopted in discourse analysis and text linguistics where it is often used synonymously with the older term, *register*. In fact the term has become so commonplace that in everyday speech it may be used for anything that may constitute a class or kind. As a result, it is used in media to classify films or TV programmes. As such, we hear about the genres of horror film, soap opera, sitcom and documentary, etc. It is even used for material objects. For example, I recently came across such a misuse in a computer magazine in connection with notebook computers: "PC Labs collected 34 examples of the genre, and sorted the best buys from the goodbyes."

This is because the urge to classify springs eternal in man: it helps to streamline the activities of a society or a group. For Lemke (1985:278), "the semiotic of Genre ... tries to capture the typology of meaningful kinds of social action in the community ..." On the need to classify and discover patterns, Lemke further remarks:

> We make meanings through the relations, and the non-relations, of texts and actions that reach to the highest orders of contextualization, the 'deepest' pattern of our social system of action and meaning.
>
> *[Lemke, 1985:292]*

And for Todorov (1990:20), "genres arise from the codification of discursive properties":

> Genres are ... entities that can be described from two different viewpoints, that of empirical observation and that of abstract analysis. In a given society, the recurrence of discursive properties is institutionalized, and individual texts are produced and perceived in relation to the norm constituted by that codification. A genre ... is nothing other than the codification of discursive properties.
>
> *[Todorov, 1990:17-18]*

As such, a genre is the child of culture, and as culture is dynamic, always in a flux of change, its offsprings are bound to change. New genres appear and old disappear, not altogether but by being transformed into new "by inversion, by displacement, by combination" (Todorov 1990:15). Moreover, a genre may gradually become institutionalised, and then come to be used as a yardstick to judge future productions within that genre. As Todorov remarks:

> Genres communicate indirectly with the society where they are operative through their institutionalization.... Like any other institution, genres bring to light the constitutive features of the society to which they belong.
> *[Todorov, 1990:19]*

If there were only one notion of genre, things would be simpler. However, there are as many notions of genre as there are bases on which a definition could be formed. As Colie (1973:23) remarks: "Within the idea of genre -system ... various notions of genre competed for attention and imitation — Sidney's *Defence* lists the kinds by substance as well as by form." In the systemic linguistic tradition, attempts have been made to distinguish genres in terms of field, mode and tenor (Gregory 1985; Hasan 1978, 1979, 1984; Lemke 1985; Martin 1985; Miller 1984; Smith, Jr. 1985; Ventola 1984, 1988; for a discussion of this trend see section 2.1.2.2 below). According to Swales (1990:34), the notion of genre has been understood in different ways. Some consider it as a "classificatory category" (Ben-Amos, 1976) while others see genres as *form*.

Even in literature, "Works by the same author and those written in the same language or the same period make up distinct groups ..." (Hernadi 1972:1). Thus, we have Elizabethan, Augustan, Romantic, Victorian and Modern literatures with further sub-divisions into poetry, drama and novel. One may thus compare the Elizabethan Sonnet with the Romantic or the Shakespearean Sonnet with the Petrarchan and so on. I do not quite agree with Blanchot (1982:220) when he says that literary genres no longer have any significance. Neither is it absurd "to ask whether *Finnegan's Wake* is a prose work or not, or whether it can be called a novel" as by asking the very question we confront the significance of genre distinction. As such, I concur with Hernadi:

> My conviction that genre concepts should be employed and transcended rather than ignored, codified, or rejected seems to be shared by many modern critics.
> *[Hernadi, 1972:viii]*

It is therefore important to look at how genres are classified. We shall look at this classification from two perspectives: traditional and systemic linguistics.

2.1.2 Generic Classification

2.1.2.1 Traditional View of Genre

In the traditional or literary view of genre, literary works are seen to belong to one of the three main genres: the poetic, the dramatic, and some of the prose kinds (including the narrative and other prose works or essays of literary value). Literature and the concept of genre are so inter-related that one cannot be conceived without the other:

> In literature, the basis of resemblance lies in literary tradition. What produces generic resemblances, reflection soon shows, is tradition: a sequence of influence and imitation and inherited codes connecting works in the genre.
>
> *[Fowler, 1982:42]*

And this tradition dates back to the Greek tripartite system. It should be remembered, here, that in the classical tradition this division is based on the manner of doing something; in other words, *style*. But there are departures from this tradition. For example, Sidney lists the kinds both by substance and form in his *Defence*. And Wellek & Warren (1963:231) suggest that such grouping should be based 'upon both outer form (specific metre or structure) and ... upon inner form (attitude, tone, purpose — more crudely, subject and audience)." One may face dilemmas if one accepts either the form or the substance as the defining generic feature — dilemmas such as whether Pope's *Essay on Criticism* is a poem and whether Joyce's *Finnegan's Wake* is a novel or not. As Fowler (1982:55) notes: 'Every genre has a unique repertoire, from which its representatives select characteristics. These distinguishing features, it is worth noting, may be either formal or substantive." Moreover, Fowler (passim) repeatedly argues that genres do not provide a means of classification; instead, they are instruments of reconstruction, interpretation, and communication:

> (...) genre theory ... is properly concerned, in the main, with interpretation. It deals with principles of reconstruction and interpretation and (to some extent) evaluation of meaning. It does not deal much with classification.
>
> *[Fowler, 1982:38]*

What Fowler is suggesting, I think, is that when we read a poem (or for that matter a play or a novel), we readily begin to interpret its meaning rather than waste our time on questioning whether it does belong to the poetic genre that it claims it belongs to. As Fowler (p. 38) remarks: "We identify the genre to interpret the exemplar." The question 'what poetry is' will even try the mind of an Aristotle. Fowler (p. 43) believes that it is difficult to decide in just what sense a feature found in a genre is generic. In his view such an investigation is, any way, irrelevant: 'But for criticism of subsequent contributions to the genre, the source of genre-linked features may be quite irrelevant. What matters is the coding rule and its immediate application, not how it came to be known." Concluding his discussion of the family resemblance theory, Fowler (p. 41) remarks: "Genres appear to be much more like families than classes."

Though, on the whole it may be difficult to define what a poem is, or what a novel or a play is, and what exactly it is that makes a poem a poem, a novel a novel, and a play a play, no one will ever take a poem for a novel, or a novel for a play. The very strength of literature comes from this undefinability:

> The undefinability of the type will be seen as a potential strength if one considers the fertility of literary invention. Definitions of genres can hardly be stated, before they are falsified.
>
> *[Fowler, 1982:42]*

We shall see in the following section what the systemic-functional theory has to say about genres and whether it provides any answers to the undefinability of this elusive concept.

2.1.2.2 Systemic View of Genre

A number of papers (Harris, 1988; Hasan, 1978, 1979, 1984, 1989; Martin, 1985; Ventola, 1984) have attempted to classify (and define) generic properties of texts from a systemic-functional perspective. Apart from Harris's, these papers analyse brief spoken encounters, such as service encounters and nursery rhymes. Generally, in the systemic linguistic tradition, the notion of register (and that of genre) is characterised by the three variables which make up the context of situation, namely, field, tenor and mode (see Halliday, 1964, 1976, and 1989).

Some systemists (e.g., Gregory, 1985) use the term *generic situation* to refer to the context of situation when dealing with genres. Generic situation is the same as the typical context of situation of items ascribed to the same genre and, therefore, as most systemists believe, can be described in terms of field, tenor and mode. But for Halliday (1978:133), a text's generic structure is "outside the linguistic system; it is language as the projection of a higher-level semiotic structure." And for Ellis (1987:123), generic structure is non-linguistic structure by which he means the "structure of the 'content' of a text" (p. 124). Similarly, Jean Ure (pers. comm.) remarks that "language functions differentiate *registers*, structure differentiates *genres*." As such, one genre is distinguished from another on account of structural features, also referred to as *generic features*. However, it is difficult to decide which features found in a genre are exclusive to that genre and which are not.

Halliday's (1978) assertion that genre structure is 'outside the linguistic system' clearly implies that genre and register are two distinct concepts; however, it would appear that the two terms are often used synonymously without sharp distinction in the literature: "In the remainder of this report we will examine those registers (or genres to use the more literary term) which teachers implicitly expect students to master" (Martin and Rothery (1981). And Hasan (1989), for example, seems to mean 'genre' when she writes 'register, and, I presume, vice versa:

> (...) the features, the factors, which allow us to judge whether or not a text is complete are essentially the same features that also allow us to identify its *register, i.e. genre*. (emphasis added)
>
> *[Hasan, 1989:109-10)*

Lemke (1985:276) suggests that the notion of genre may be understood in terms of register. In his view, register "can be regarded as the paradigmatic system of discourse, providing a systematic typology of texts." Martin (1985) considers genre, register and language as three 'semiotic communication planes' in which genre is realised by register and register, in turn, is realised by language. Genre, in this scheme, occupies the highest semiotic plane (in terms of abstraction) while language occupies the lowest with register in between (see Figure 2).

The relationship between the semiotic planes is described as expression-form: language is the expression-form of register, and register is the expression-form of genre. In this scheme, language is the *resource* (linguistic repertory) from which *choices* (patterns of linguistic choices) are made to make up a register. These choices are then *structured* in accordance with the genre that the choices purport to realise. Also in this scheme, as Ventola (1988:57-58) puts it, "genre and register can both be perceived only by looking at the linguistic realization of text instances of genres and register." Continuing the same line of argument, Nesbitt and Plum (1988:32) state

Figure 2: Martin's (1985) three semiotic planes.

that register and genre are "predictive of patterns of language, which are in fact their linguistic realization."

Kress (1985:29) is, perhaps, the first to give some indication that the two terms are distinct: "The presence of a range of *linguistic features* does not of itself determine the form of the texts; that is determined by the *formal features* of particular genres." He further says that "The form of a text is ... a factor of the conjunction of the *linguistic features* specified by the discourse and of the *formal aspects* of the genre together" (emphasis added).

In a recent work, Kress (1993) identifies two approaches to the description of the term, *genre*: one developed by Martin and Rothery in which the term "covers everything there is to know linguistically about text"— that is "the whole complex of factors which needs to be described and understood about a text" (p. 32); and the other expounded by Kress himself in which the term *genre* is used to cover only one aspect of the text: 'textual structuring' (p. 32). According to him:

> Language always happens as text; and as text, it inevitably occurs in a particular generic form. The generic form arises out of the action of social subjects in particular social situations. Consequently, the action of individuals as social subjects is at the centre of the production of text in generic form...
>
> *[Kress, 1993:36]*

Couture (1986) shows how the two notions should be kept apart. According to her, 'register imposes constraints at the linguistic level of vocabulary and syntax, whereas genre constraints operate at the level of discourse structure.' She further states:

> Unlike register, genre can only be realized in completed texts or texts that can be projected as complete, for a genre does more than specify kinds of codes extant in a group of related texts; it specifies conditions for beginning, continuing and ending a text.
>
> *[Couture, 1986:82]*

Swales (1990) does not distinguish between register and genre as such apart from referring to Couture, Ventola, and Martin, and although some of his genre-defining features are also characteristic of registers, he makes one important observation that is crucial to distinguishing register from genre. Referring to 'good news letter' and 'bad news letter' within administrative correspondence, Swales (p. 53) argues that though "both kinds of letter [seem to] constitute a single genre of *responses to applications*, ... a little reflection will show that, *while the textual environment and the register may be the same, the rationale is sufficiently different to require a separate genre for each*" (2^{nd} emphasis added). What Swales is suggesting here is that if two texts have the same register, they do not necessarily belong to the same genre. For him, the deciding factor is the difference in rationale. As such, Swales also puts genre on a higher plane than register as does Martin (*ibid*).

I have argued so far that register and genre are two distinct notions and that they must be kept apart. But just this realisation will not help much. It is also imperative to restrict the use of the term 'genre'. Here, I am at one with Miller (1984:151) who says that "if the term 'genre' is to mean anything theoretically or critically useful, it cannot refer to just any category or kind of discourse."

Although, on the basis of the foregoing discussion, it would appear that communicative events such as service encounters (Hasan 1989), chats, debates and salesmen's routines (Brown & Yule 1983) do not comprise genres, there is one situation in which some of these registers could acquire the status of genres. Here, I have in mind Martin and Rothery's (1981:3) comment that "There are in fact few places in our culture where registers *are* explicitly taught: in for example the training of salesmen." It is possible that registers such as service encounters, salesmen's routines, etc., have acquired their 'obligatory' elements (the basis on which it is argued they are genres) through being taught as part of training. On this account, some registers could never become genres: no one needs training to chat with one's friends, or does one?

A group of people who thus adopt certain conventions (through training) in order to communicate among themselves comprise a discourse community. These conventions then become standardised and evolve into written genres. As these two terms, genre and discourse community, are closely linked, they are jointly discussed in the next section.

2.1.3 Genre and Discourse Community Defined

So far we have been reviewing traditional (literary) and systemic views of the term, genre, without providing a definition of it. According to Fowler (1982:40), "genres at all levels are positively resistant to definition" mainly because "Either defining characteristics are absent altogether, or they are limited to meagre distinctions that do no more than subdivide the genre." Definitions of genre have been framed, most commonly, in terms of similarities: 'similarities in strategies or forms in the discourses' (Hart 1971; Campbell 1973; Raum & Measell 1974; Black 1978); 'similarities in audience' (Mohramann & Leff 1974); 'similarities in modes of thinking' (Gronbeck 1978; Rogers 1982); and 'similarities in rhetorical situations' (Windt, Jr.

1972; Ware & Linkugel 1973; Halloran 1978). However, Miller (1984:151) argues that "a rhetorically sound definition of genre must be centred not on the substance or the form of discourse but on the action it is used to accomplish." A definition of genre based on this principle is provided by Martin (1985:248): "Genres are how things get done, when language is used to accomplish them." It also implies that genres are different, for they do different things.

On the other hand, Cairns (1972:6) holds that "Every genre can be thought of as having a set of primary or logically necessary elements which in combination distinguish that genre from every other genre." Here again, Martin's definition fulfils this criterion:

> a genre is a staged, goal-oriented, purposeful activity in which speakers engage as members of our culture.
>
> *[Martin, 1984:25]*

A very comprehensive definition of genre, however, is provided by Swales (1990) in terms of his understanding of the concept of discourse community. His definition of genre is based on four related strands which can be summarised as follows:

1. A genre comprises a class of communicative events with shared communicative purposes that are recognised by expert members of the discourse community, and which constitute the rationale for the genre.
2. This rationale shapes the schematic structure of the discourse and influences and constrains choice of content and style.
3. Communicative purpose keeps the scope of the genre narrowly focused on comparable rhetorical action.
4. In addition to purpose, exemplars of a genre exhibit various patterns of similarity in terms of structure, style, content and intended audience.

[Swales, 1990:58]

These four strands — communicative purpose, schematic structure, rhetorical action, and patterns of similarity across exemplars of a genre — not only identify the defining characteristics that were thought to be absent (Fowler, 1982), but also satisfy other principles that have been suggested in the literature (e.g., Miller, 1984; and Cairns, 1972). We also see that other things in this definition are also situated in the right perspective: communicative events, communicative purposes and expert members are all the concomitants of discourse community. As the notion of discourse community is important for the understanding of the term, genre, and the genre of the research article, let us turn to a brief discussion of the concept.

The concept of *discourse community* derives from the long-established concept of *speech community* as used in sociolinguistics (see Hudson, 1980). The new term is a 'convenient translation' of the earlier, sociolinguistic, term, a point of departure for those engaged in composition studies to define their purposes, their focus on the written rather than the spoken medium:

> Only recently have compositional studies begun to investigate communities of writers and readers, though the terminology seems to be changing, to "discourse communities," in order to signal the focus on the written rather than just the spoken.
>
> *[Freed and Broadhead, 1987:154]*

This focus on the writer, the written and the discourse community is warranted, for a discourse community can achieve not only standardisation, but also autonomy, historicity and vitality. According to Freed and Broadhead (1987:155), a discourse community achieves *standardisation* through the activities of publishing research in journals, holding conferences, setting up associations and workgroups, and compiling bibliographies. Standardisation fosters *autonomy*, making a discourse community unique. To increase its autonomy and uniqueness, a discourse community takes cognisance of its *historicity*: how it came to acquire, as it did, its present discourse forms, and discourse practices. Standardisation, autonomy, and historical orientation lead to *vitality* — "interactive networks that use language to perform the community's vital functions" (p. 155). A discourse community, as such, acquires bodies of knowledge, conventions, and strategies that govern a writer's rhetorical decisions, obliging him to adhere to the norms accepted and practised within his discourse community.

These norms and discourse conventions regulate the behaviour of the members of a discourse community. Texts produced according to these norms and conventions evolve into genres, which then act as exemplars of standard practice to be followed by new members. Genres, as such, are the properties of discourse communities (Swales, 1988:211); that is, they are established and propagated by discourse communities. Swales (1988, 1990) further argues that discourse community is a sociorhetorical construct and it needs to be distinguished from the term, speech community, which is a sociolinguistic construct. Accordingly, Swales (1990:23-32) distinguishes the two constructs from one another on the following three accounts:

1. **The first account concerns medium.** The members of a discourse community are more likely to communicate with other members in distant places through the medium of writing. Members may belong to different speech communities.
2. **The second concerns the nature of the two.** Speech community is a *sociolinguistic* group while discourse community is a *sociorhetorical* group. The primary determinants of the linguistic behaviour of the former are social while those of the latter are functional. A speech community has socialization and group solidarity as its primary communicative needs while a discourse community, primarily, has pursuits other than socialization or group solidarity.
3. **The third concerns membership.** Speech communities are centripetal as they tend to absorb people in their folds. On the other hand, discourse communities are centrifugal, for they tend to separate people into occupational or specialty-interest groups. Membership of a speech community happens by birth, accident or adoption whereas that of a discourse community eventuates due to training or relevant qualification.

The third point implies that the members of a discourse community need not be members of one speech community. A discourse community is a heterogeneous group with members having different origins and different first languages brought together by a shared set of predefined goals. These predefined goals determine the cognitive structuring of information in a genre, giving it structural regularities that help members of a discourse or professional community achieve their communicative purposes in a standardised way.

Although on the basis of the foregoing discussion, it would appear that no two discourse communities will have a similar view of their discourse activities and genres, it would be counterproductive to attempt to postulate a separate RA genre for each discipline. The research article genre has to be treated at a level of generality that relates to the activity of scientific inquiry in general, and not one operating within a particular discourse community. This view is supported by cognitive and schema theoretic research on discourse processing. For example, it has been shown that if readers have some background knowledge of the content and structure of the reading task, they are usually better able to deal with it. This background knowledge is known as ***schemata***. Hewings and Henderson (1987) even suggest a link between genre and schemata in the following words:

> Reading articles can be seen as demanding the creation of new sets of schemata overlapping with those needed for textbooks, but generally of a more elaborate and evaluative nature. Development or appropriate schemata can be enhanced by viewing the texts to be read as belonging to a different genre or sub-genre.
>
> *[Hewings and Henderson, 1987:173]*

Swales (1990), too, acknowledges the role of schemata in genre-based studies. He holds that there exists a close intrinsic relationship between the two (p. 88). In his seminal study of article introductions, Swales (1981) argues that a study of genre must attempt to establish a "viable correlation between cognitive, rhetorical and linguistic features" (p. 10) of the text. In this case, an understanding of the cognitive processes involved in reading (and writing) is provided by research in schema theory. Thus, it is highly desirable to give a brief review of the schema-theoretic view of reading comprehension as it has obvious implications for the reading and writing of scientific RAs.

2.1.4 Genre and Schemata

The concept of *schemata* first appeared in a work by Bartlet (1932) dealing with 'story-grammars', i.e., the arrangement of information in stories and its subsequent storage in memory. Subsequent research on the psychological processes involved in reading comprehension has resulted in the extension of this concept to any kind of reading. It is now believed that background knowledge plays a vital role in reading comprehension:

> One type of schema we human processors are claimed to possess is background knowledge about the formal, rhetorical, organizational structures of different kinds of texts. In other words, part of our background knowledge includes information about, and expectations of, differences among rhetorical structures — e.g. differences in genre, differences in the structure of fables, simple stories, scientific texts, newspaper articles, poetry, etc.
>
> *[Carrell, 1983:83-84]*

Since texts have both form and content, Carrell (p.83) makes a distinction between *content schema* and *formal schema*. She has also tried to establish the role of the latter in reading comprehension independent of the former. Researchers have been able to demonstrate the relevance of formal schema to ESL reading and writing (see Carrell, 1984a for a review). In yet another study, Carrell (1984b) ventures to propose, on the basis of her findings, that ESL readers would appear to be similar to native readers if the ESL readers "possess the formal schemata against which to process the more highly structured types of discourse" (p. 464). Schema-theorists also claim that the relative ease or difficulty of a text/discourse depends on how and whether or not its rhetorical "structure relates to a reader's internalized formal schemata" (Carrell, 1987:466-67). This clearly has implications for reading and writing in EAP, and more so in research settings where the scientists, both NSE and NNSE, already possess the content schemata of their respective fields. It would be, therefore, highly fruitful to teach learners to identify different discourse structures (Carrell, 1984b), such as that of the scientific research article.

One strand in Swales' definition concerns *rhetorical action* (see above, Section 2.1.3) which implies that genre is also related to rhetoric. This relation is the topic of the next section.

2.1.5 Genre and Rhetoric

In ancient times, the term, rhetoric, referred to the art of making eloquent speeches, valued both for aesthetic appeal and practical ends. For some time, rhetoric had acquired some pejorative connotations mainly because of the way it was practised by the sophists: to win arguments without any regard for truth. Hence, as early as Socrates, rhetoric had been associated with concealing rather than revealing truth, and with artificiality of thought and expression. Plato deprecated rhetoric the way it was practised by the sophists — devoid of substance. Although Aristotle had valued it, rhetoric had a long way to go to shed the burden of the sophists' verbal trickery, and be revived. Rhetoric, at present, no longer has its pejorative associations; rather it is now considered as 'the wit of persuasion', the *raison d'être* of all argumentation among both linguists and non-linguists alike. While the linguists rediscovered it (a) as a set of techniques to be taught to the students for improving their writing (those concerned with the teaching of writing), (b) as a set of conversational 'principles' and 'maxims' (Leech, 1983), and (c) as principles of information structure and 'signalling strategies' (Jordan, 1984), the non-linguists rediscovered it as a means of improving the efficiency of verbal behaviour in their own disciplines (e.g., McClosky, 1986; Mason, 1989; Simon [ed.], 1989). This revival of rhetoric within both the spheres comes from Perelman and Olbrechts-Tyteca's *The New Rhetoric* (1969). For them, rhetoric is effective argumentation. Toulmin's (1958) theories of argumentation have also been instrumental in this revival, especially in the non-linguistic sphere. Under this influence, rhetoric is no longer associated with 'a body of theory' or 'a set of artificial techniques' but is regarded 'as an integral component of all human discourse':

> Rhetoric, for the proponents of the new rhetoric, is a practical discipline that aims not at producing a work of art but at exerting through speech [and writing] a persuasive action on the audience.
>
> *[Encyclopaedia Britannica, Vol. 26, 1991:762]*

The text is perceived as a suffusion of content, intention, structure, audience, and situation. Provided that we know about these variables, we can discover within reasonable limits whether a certain text is likely or unlikely to achieve its intention.

In the sphere of linguistics, the interest in rhetoric may be linked to a concern with taking the use of language beyond the sentence level to a study of the global patterning of texts (e.g., Kaplan, 1966, 1988; Mann & Thompson, 1987). But is the global patterning of text the only aspect of rhetoric? Billig (1987:58-59) makes a distinction between the ***rhetoric of form*** (cf. *formal schema*, Carrell, 1983; *formal features*, Kress, 1985:29) and the ***rhetoric of content*** (cf. *content schema*, Carrell, 1983). While the former appears to correspond to generic structure ('arrangement' or order of arguments), the latter is concerned with 'invention' (construction of arguments) and expression or style (*op cit.*: 56-57). Billig (p. 59) warns against a sole reliance on *form* to explain rhetoric, pointing out that the failure of many a social psychologist to describe effective argumentation has been due to their neglect of 'the rhetoric of content' (p. 73).

But is linguistics capable of describing the 'rhetoric of content'? We know that modern linguistics is descriptive rather than prescriptive, that it does not pass evaluative judgements. Although linguistics can detect language use problems, it does not rate one text as written better than another if both are well-formed and free of such problems. But a text free of language use problems does not necessarily mean that the text is also well-written (Raskin and Weiser, 1987). There are other, extralinguistic dimensions to well-writtenness, too:

1. appropriateness for the audience
2. good and correct style
3. appropriateness for the purpose
4. conformity to the cultural rhetorical conventions
5. conformity to format-related conventions

[Raskin and Weiser, 1987:260]

Raskin and Weiser point out that although these dimensions can be detected in texts, they are not concerned with linguistic well-formedness of texts (p. 261). And there also are other, non-linguistic dimensions which cannot be so easily detected in texts, such as subject, purpose, audience, or structure of a text (p. 265). However, "Once writers make these choices and produce texts, linguistic applications ... can help them assess whether *the language of the text contributes to or hinders its communicative goal* (p. 265, original emphasis). According to Dillon (1991):

> To understand how the language of a particular text works, that is, we must understand how it is accommodated to the audience, occasion, and purpose at hand....[But] The audience, occasion, and purpose are never merely "at hand" — texts frequently must conjure up an occasion for themselves, announce an ostensible purpose, and cast a role for the reader to play, all while crafting a persuasive persona for themselves.
>
> *[Dillon, 1991:8-9]*

Whenever we, as readers, encounter a text, we can readily ascertain whether the text is meant for us or not even if the text addresses some very common topic. But an analyst has to read not only general texts (such as the ZPG letter; Mann & Thompson, 1992) but also highly professional ones to perform his job as analyst (such as geology research articles). In order not to be hampered by the unfamiliarity of the content of professional texts, the analyst needs to concern himself with the linguistic, non-linguistic and extralinguistic features of such texts. The scientific research articles are particularly amenable to such analyses, for, in addition to having an overall genre structure and rhetorical organisation, they are vested with a clear focus with respect to audience, occasion, and purpose. Every genre will have its own unique configuration of focus, and linguistic, non-linguistic and extralinguistic features. Any change in this rhetorical configuration will give birth to a new genre. A case in point is science popularisation of important scientific discoveries. Even if the two (RA proper and its journalistic version) are written by the same writer, they differ in significant ways, not only in rhetorical features but also in generic structure (Fahnestock, 1986; Myers, 1986, 1988; Nwogu, 1990). According to Fahnestock (1986:279): "a change of audience brings a change of genre." And, too, during a change of genre, from the forensic (the RA) to the epideictic (the popular), the information also suffers a sea change.

This change in genre and information occurs because of a change in the author's intended purpose. Being structured by the author's intention, the text can, therefore, be viewed as the 'embodiment of that intention'. Since rhetoric is the wherewithal for achieving the writer's intention, it must conform to that intention. But different cultures are assumed to have different rhetorical patterns, as already touched upon briefly in the previous chapter. This assumption certainly has implications for the NNSE writer's intention: imagine two writers with the same intention (scientific persuasion) employing different rhetoric to assert, argue, persuade, and make claims, one following the conventions of international scientific reporting, and the other those of his own native culture. According to this assumption, the second report will be considered suspect by the international readership, though not by readers from the writer's own cultural background. As this discussion falls in the domain of contrastive rhetoric research, let us mark it with a new section.

2.1.6 Rhetoric and Culture

Discourse based differences in non-native writing have been attributed to cultural rhetorical patterns (Kaplan, 1966). Kaplan suggests that the rhetorical patterns of an ESL learner's L1 or culture may be evident in the rhetorical organisation of his ESL writings. According to him:

> Logic (in the popular, rather than the logician's sense of the word) which is the basis of rhetoric, is evolved out of a culture; it is not universal. Rhetoric, then, is not

> universal either, but varies from culture to culture and even from time to time within a given culture. It is affected by canons of taste within a given culture at a given time.
>
> *[Kaplan, 1966:2]*

Based on some 600 L2 student essays, Kaplan proposed five cultural thought patterns: English, Semitic, Oriental, Romance, and Russian. One main problem with Kaplan's study was that he took it for granted that the English thought in a straight line: "The thought patterns which speakers and readers of English appear to expect as an integral part of their communication is a sequence that is dominantly linear in its development" (Kaplan, 1966:4). But this is not necessarily true as numerous variations exist (see Braddock, 1974). Kaplan (1987) himself recognises the negative implication of his earlier assumption: "I understand that to a certain extent my observations were constrained by virtue of the fact that my focus was on the English language, while my conclusions implicated other languages" (p. 10).

The potential application of this theory in ESL classrooms was readily recognised, and soon the instructors began to exhort their ESL students not to think in circles or in zigzags but in straight line, like the English did, if they wanted to write in a native-like style. But as Péry-Woodley (1990:147) points out: "It has often been forgotten that Kaplan's concern was with paragraph and not text development." She also points out that Kaplan's paper "conflates, inexplicitly and unhelpfully, approaches belonging to ... comparative IL research (i.e. IL v. target language) and approaches belonging to contrastive rhetoric (i.e. native L1 v. native L2)."

However, I believe that it is not important to learn whether people think in straight lines or circles or zigzags, what is important to remember is that the writings of NNSE are liable to be different from those of NSE in different ways, explicit as well as implicit. According to Leki:

> It seems reasonable to assume that different cultures would orient their discourse in different ways. Even different discourse communities within a single language, such as those constituted by different academic disciplines, have different writing conventions: preferred length of sentences, choice of vocabulary, acceptability of using first person, extent of using passive voice, degree to which writers are permitted to interpret, amount of metaphorical language accepted. If different discourse communities employ differing rhetorics, and if there is transfer of skills

> from L1 to L2, then contrastive rhetoric studies might reveal the shape of those rhetorical skills and strategies in writers from different cultures.
>
> *[Leki, 1991:124-25]*

Despite the fact that Kaplan's seminal article (1966) has been criticised on different grounds (see, for example, Hinds, 1982), it is generally agreed that transfer of rhetorical organisation from L1 to L2 indeed occurs: "various cultures organize the development of ideas differently when writing expository prose and ... these differences persist when speakers of these cultures learn to write in a new language" (Ostler, 1987:169). Ostler (*ibid*) further states that "experienced ESL writing teachers can identify Arabic-speaking students' English essays as having been written by Arabic-speakers, even when these essays are free of grammatical errors." She claims that this is due to the different rhetoric patterns used by the Arabic-speakers. In a similar vein, Harder writes:

> Complex communication difficulties involving stylistic, logic and clarity in the discourse structures of advanced English compositions by writers from another language and culture cannot be explained as merely insufficient knowledge of English grammar, diction or idiom. Such problems do not only involve linguistic differences in the native (NL) and target language (TL) but encompass different stylistic habits, different ways of thinking, and different cultural values.
>
> *[Harder, 1984:115]*

Harder believes that the English writings of advanced learners "will incorporate a mixture of the logic and rhetoric of the TL and NL cultures experienced by the writer" (pp. 116-17).

However, one main change has been noticeable during the 1980's: "the false assumption that NL interference was either the sole or at least the main cause of learning difficulty" (James, 1990:205) appears to have been dispelled. Moreover, the potentials of positive or facilitative NL transfer have also been recognised (Ringbom, 1987).

It is possible to identify two basic approaches to contrastive rhetoric: (a) with focus on L1, and (b) with focus on L2. And the texts examined in both type (a) and type (b) studies can be classified as student essays and professional, published work, thus making comparison of the findings across the studies difficult. Studies examining L2 texts written by NNSE students, according to Leki, also have to "face the burden of addressing Mohan and Lo's (1985) argument that what is being identified as non-English is, in fact, merely nonskilled, developmental writing" (Leki, p.126). Texts compared across cultures must not only be of the same genre, but also, as Purves (1988:14) argues, must exemplify "similar setting or similar function across the groups of writers." The following five rules, Purves proposes, must be followed in any contrastive study:

1. The settings in which the writing occurs should be as similar as possible.
2. The writing task should be consistently set in its function and cognitive demand as well as in the specific subject matter.
3. The language (i.e. native [L1] or foreign [L2]) in which the writers are writing must be defined [specified(?)].
4. The occupation of the writers should be similar, or if not, should be defined and accounted for as a variable.
5. The [level of] education of the writers should be similarly defined and described.

[Purves, 1988:16]

Very few studies have so far taken account of these recommendations. And still fewer are studies that follow a practice which poses almost none of these problems, that is, comparing L2 professional, published works by NNSE with those written by NSE (Taylor & Tingguang, 1991; St. John, 1987). As Péry-Woodley (1990:144) remarks: "There appears to be very little research concerned with comparing/contrasting what non-native and native speakers of a language do in a comparable situation."

And there is a still greater dearth of research contrasting scientific RAs written by non-native and native speakers of English. I believe that a contrastive study of NNSE and NSE RAs within a single discipline, as undertaken in the present study, would mostly overcome the problems mentioned by Grabe (1987) and Mohan and Lo (1985).

Péry-Woodley (*ibid*) would characterise such studies as *Comparative Inter-language Research* (IL v. target language). Such studies answer the question: 'How similar (or different) are English as a first language (used/written by NSE) and English as a second language (used/written by NNSE)?' (cf. van Naerssen, 1980).

Although studies which contrast expository compositions by ESL student writers with those written by NSE students are only indirectly relevant to the present study, it may still be of benefit to review a few of them. Results of a study conducted by Mohan & Lo (1985) in British Columbia in which they contrasted the compositions of Grade 12 NSE students with those written by NNSE students revealed no significant differences in the organisation or any other aspect of the composition. The results suggest that:

> the first language does not necessarily influence composition organisation in the second language, particularly when non-native speakers receive the same composition instruction as native speakers.
>
> *[Mohan and Lo, 1985:526]*

In an interesting study Doushaq (1986) analysed the Arabic and the English compositions of two groups of Arab students, one majoring in Arabic and the other majoring in English. He found that compositions written in Arabic by fourth-year students from the first group (majoring in Arabic) were the least coherent, but those written in Arabic by students from the second group (majoring in English) were considered to be the most coherent though their English compositions were less coherent. This, Doushaq (p. 35) argues, was due to the fact that students in the English Department were offered special courses for the development of writing skills in English. These skills they appeared to utilise more successfully when composing in Arabic than in English. Although these two studies show that ESL writing instruction does play a role in reducing transfer of rhetorical patterns from L1 to L2, an important corollary to Doushaq's study, so far unrecognised, is that ESL writing instruction influences one's writing skills in L1. This certainly has implications for studies comparing compositions in L1 and L2 by the same writers.

It is, therefore, possible to discover two kinds of L2 or TL writings in a culture: one closer to the rhetoric of native culture, and the other closer to the rhetoric of the TL culture. For example, both Kachru (1984) and Eggington (1987) found Hindi & English style, and Korean & English style texts in their respective studies of Hindi writing and Korean academic writing. In Kachru's case, it may be due to India's colonial history while in Eggington's, it depended on whether or not the Korean author had had training in an English-speaking country.

Scarcella (1984) studied the introductions to expository essays written by native and non-native English speakers to discover how they orientated their readers. He found that the NNSE students used a very limited variety of linguistic devices to engage the attention of their readers (p. 671). Their orientations were also found to be longer (p. 683). Most important, the NNSE writers avoided asserting the importance of their themes:

> Non-native English writers also differed from their native English counterparts in their use of direct assertions. Whereas native English writers often used such adjectives as *important, shocking*, and *fascinating* to establish the importance of their themes, the non-native English writers — again, especially those of Asian first language backgrounds — sometimes preferred statements which downplayed the importance of their themes. This tendency may be due to cultural differences in the use of politeness.
>
> *[Scarcella, 1984:678]*

Scarcella suggests a number of directions for further research such as the effect of language transfer on the writing performance of ESL learners, the functioning and the most valued types of orientations in their L1, and the analysis of orientations in different contexts and genres (pp. 685-86).

Ostler (1988) studied the contrastive rhetoric of Arabic, English, Japanese and Spanish by analysing a total of 160 essays (40 from each group). The corpuses were drawn from essays written in English by native speakers of Arabic, English, Japanese and Spanish. She discovered that the four corpuses differed both in terms of organisation and rhetorical pattern. Her results indicate that different languages have different rhetorical characteristics which natives of those languages may implement when writing in English.

As the study by Taylor and Tingguang (1991) is of utmost relevance, it deserves a detailed review. Taylor and Tingguang analysed 31 research article introductions (11 in English from English-speaking countries; 10 in English by Chinese; and 10 in Chinese by Chinese) for the occurrence and order of Swalesian moves (4-Move model). They drew their corpus from related fields of geophysics, metallurgy & mineral processing, materials science, and materials engineering. An equal number of experimental and theoretical/methodological RA introductions were used in the analysis. The sources for the corpus were of three kinds: journals published in Canada, the UK, the USA and the Netherlands, and journals published in China, two in English and one in Chinese.

Analysis of the corpora revealed that the Swalesian pattern was employed by all three groups; however, there were individual papers in every group which did not conform to the 1-2-3-4 structure. This pattern was found to be the norm, a trend "substantially the same for each of the three groups" (p. 325). However, very striking differences emerged when variations on the Swalesian Move pattern were considered: there was a clear preference for elaborated structures in the Anglo-American introductions while a reverse trend was found among the Chinese scientists irrespective of the language in which they wrote (pp. 326-27). As far as the length of the introduction was concerned, the Anglo-American introductions were found to be 63% longer than those by the Chinese authors.

Taylor and Tingguang conclude that "there is no 'Chinese way' of writing science that is attributable to features of the Chinese language itself" (p. 330). In short:

> The Chinese scientists are less likely to elaborate the moves or use unconventional moves, and they write at significantly less length. We have suggested earlier that such differences can be ascribed to cultural factors of some kind. That which seems to stand out is the feature that ties together the Chinese propensity for avoiding elaboration, using deleting patterns, writing at less length, and citing fewer references.
>
> *[Taylor & Tingguang, 1991:330]*

One reason that Taylor & Tingguang advance for this variation is that scientific disputation does not prevail in China to the extent that it does in the west (p. 331). However, as far as the organisation of the introduction is concerned, they claim to discern "an internationalisation of scientific discourse that is nevertheless heavily qualified by significant variations in both regional and interdisciplinary cultures" (p. 332).

According to Péry-Woodley (1990:149), internationalisation of scientific discourse abolishes any need for comparison. And this may well be true because standardisation might disguise what Wong (1988) calls "written discourse accent" by which she means "something noticeably unnative-like in written discourse of advanced learners" (p. 8). According to Wong, discourse-level problems would be difficult to isolate from surface-level problems in the writings of non-native writers who do not have a good linguistic competence:

> Only when the learner's command of English falls within a very narrow range of delicacy, i.e., when his English is good enough to be free of sentence-level surface errors but not of discourse-level problems, would written discourse accent be readily discernible as a separate difficulty peculiar to those of his language background.
>
> *[Wong, 1988:11]*

There are several other methodological and conceptual issues which need to be considered before the usefulness of contrastive rhetoric can be established. I shall take them one by one.

1) One main issue facing contrastive rhetoric is to determine how it is possible to demonstrate that the differences found in L1 and L2 texts are due to different cultural thought patterns of the writers. This relates to the problem of the mechanism of how culture influences thought patterns and rhetorical patterns in writing. Harder (1984:117) maintains that it is difficult to demonstrate that differences in logic and coherence in L2 texts are due to cultural differences. The differences may as well be due to developmental factors in language learning (Mohan and Lo, 1985:517). Harder further argues:

> Identifying differences in the sample essays is easier than demonstrating how these are related to culture, unless we restrict the discussion to formal methods of organization, development and argument that exist in the tradition of one culture but not another.
>
> *[Harder, 1984:117]*

As such, Wong (1988) suggests that in order to discover the non-native written discourse accent, writings that are free from surface-level errors should be analysed (p. 11; quoted in full above).

2) Most contrastive rhetoric (and writing process) studies have focused on *expository prose* texts. In this respect, Grabe (1987) points out a recurring problem: the need to define the term, *expository prose* objectively, for he believes that the term itself is too crude (p. 115). Grabe has been able to show that expository prose is a 'distinct major genre' with a number of text-types which a contrastive rhetoric study must be aware of (p. 135). Discussing the implications of his research for contrastive rhetoric research, Grabe argues:

> (...) this approach provides a way to determine whether text types exist, how they can be defined, and how they can be related to other text types. If contrastive rhetoric is to examine text materials in a number of languages, at some point in future, the research will have to establish which texts in different languages are, in fact, similar.
>
> *[Grabe, 1987:136]*

3) The studies so far discussed and referred to have used various types of data for analysis. For example, Kaplan (1972) and Mohan & Lo (1985) used written compositions by learners still in the educational system; and Clyne (1987) and Eggington (1987), the writings of experienced academics, etc. The main problem with such diverse studies, as Taylor & Tingguang (1991:321) note, is that the results from one cannot be correlated to those from others. As far as genre is concerned, one needs to be as specific as possible; for example, if one is analysing academic writing, one must be specific about the discipline (Taylor, 1986; Ballard & Clancy, 1988; Park, 1988). Mohan & Lo, (1985) may be criticised on the grounds that they do not specify the kind of academic writing they examine. In this connection, Taylor & Tingguang (*ibid.*) stress the need to isolate three broad issues in order to have a firm methodology: "Controlling for the authorship, genre, and content of the data used; being clear about the linguistic and research model chosen; and establishing the reliability of the analyses undertaken." Taylor & Tingguang attribute the discrepancies found in the contrastive studies "to a lack of explicitness about some of the assumptions concerning the nature of the connection between language and culture and to the nature of the questions being asked" (pp. 322-23).

4) Péry-Woodley is critical of Kaplan's early work and various other studies for treating language as transparent and for not broaching "the problem of the

relationship between local features and the more global categories of rhetorical structure" (p. 149). For example, it has been found that "extensive embedding of phrases and subordinate clauses is recognized as a sign of syntactic maturity" (Hunt, 1965; as reported by Wong, 1988:9). Needless to say, such syntactic maturity will result in a rhetorical structure quite different from the one achieved mainly through coordination, additive conjuncts, and underuse of lexical cohesion. Even though non-native English writing may be devoid of all surface-level grammatical errors, lack of syntactic maturity would give it away as non-native. This may be one reason why experienced ESL writing teachers claim (Ostler, 1987:169) to be able to tell non-native English writings from native English writings even when the former are free of all grammatical errors. Similarly, Stalker and Stalker (1988:119) maintain that the surface level errors made by ESL writers are different in kind from those made by native writers which give away the former as non-native:

> our colleagues in the intensive English program and in the freshmen composition program stoutly maintain that they can easily distinguish a nonnative from a native piece of writing.
>
> *[Stalker and Stalker, 1988:119]*

The study by Stalker and Stalker supports Kaplan's more recent view (1987) that L1 rhetorical structures impinge on the acquisition of L2 rhetorical structures rather than seriously interfere with it (Stalker & Stalker, p. 126).

5) There are two issues, one raised by Mohan & Lo (1985) and the other by Leki (1991), which pertain specifically to academic writing. Mohan & Lo assert the need for "detailed comparative studies of academic discourse in a number of languages" in order to know "which aspects of academic discourse are culture-specific and which are universal" (p. 529). And Leki stresses the importance of moving beyond "the texts themselves to an examination of the rhetorical context in which they are embedded" (p. 129).

6) There are also the problems of comparability and similarity. Péry-Woodley (1990) reports a study by Régent (1985) who compared medical research articles written by French scientists in French and in English. The later were found to be more

argumentative than the former. Régent (p. 119) discovered a tendency among French scientists to follow the English model. Péry-Woodley comments that Régent's study reflects the problem of comparability in contrastive rhetoric. And Grabe (1987:136) stresses the need to first establish a similarity of texts across different cultures in order to compare them.

7) This point pertains specifically to the contrastive study of texts in L1 and L2 written by subjects having the same L1. The problem lies in the analyst's focus on patterns in the L2 and his attempt to implicate the L1 of the subjects (Kaplan, 1987:10). Doushaq (1986), as already discussed above, seems to be evaluating Arabic compositions of his subjects in terms of the discourse patterns of English when he says that the Arabic compositions of his subjects majoring in Arabic were less coherent than those majoring in English and receiving ESL writing instructions.

None of the studies reported so far appear to address all of the issues mentioned here. Hence the findings cannot be correlated to reach viable conclusions and form valid generalisations. Although the study by Taylor & Tingguang comes closest to addressing all the issues, one main problem remains: they do not mention how they made sure that the Chinese scientists writing in Chinese were not following the English model.

In the face of so many fragmentary findings, it is rather difficult to argue conclusively in what sense writing in L2 is affected by cultural differences. As it is difficult to be precise about the nature of cultural transfer (there are so many factors, and the situation is never static), more contrastive research is called for to provide a fuller account of cultural transfer, or impingement, or interference. However, if we accept that culture does shape our writing behaviour (a social activity), then, with respect to the research article genre, three questions arise: 1) what is the rationale for comparing research articles across cultures if we already know that they are different in culture specific ways? 2) And what is the rationale for teaching others to adopt the ways and conventions of the target culture, in this case the Anglo-American culture? 3) Is it not tantamount to attempting to change the cultural behaviour of NNSE writers?

The answers to these questions lie in the fact that social activities are either more or less entrenched in culture. If we were doing a contrastive analysis of genres deeply entrenched in cultures (such as, letters, including *belles lettres*, and stories, religious works, etc.), with a view to changing the writing behaviour of a people with respect to such genres, the answer to the third question would be 'yes'. However, scientific inquiry is not rooted in any particular culture: it is a universal activity, a joint venture of all humankind. It just happens that the bulk of this joint product is in English, and not in German, or Japanese, or Urdu, or Arabic. In order to contribute to this universal scientific inquiry, other cultures have to write in English if they aspire to make their impact felt. To achieve this effectively, they need to follow the universal scientific conventions and norms with respect to argumentation, persuasion, and making claims. Dillon (1991) points out that rhetoric alone is not what the theory of argumentation is all about. Rhetoric is only the process of argument. It does not include the procedure and the product of argument:

> *Rhetoric*, as the study of process, directs its attention to speakers, hearers, purposes, occasions, as they affect attempts to persuade. *Dialectic*, as the study of procedure, focuses on the argumentation pro and contra, the rules for the scrutiny of evidence and argument, opportunities for rebuttal, restatement, and clarification ... [in short] - communicative rationality. *Logic*, finally treats the product of argument in terms of the validity of arguments.
>
> *[Dillon, 1991:156; emphasis added]*

These may be termed the universal rules of science; they are not special to any one culture. But a culture may have a different view of rhetoric, dialectic, and even logic (see Kaplan, 1966) which may render one's scientific report suspicious in the eyes of the universal scientific community.

And this is the rationale for contrasting/comparing scientific research articles across genres, and for teaching other cultures to conform to these universal scientific rules. This answers the first two questions. The answer to the third question is, therefore, 'no', as the objective is not to change people's written behaviour in general, but their written behaviour in the culture of science. In this connection, Bhatia's (1993) remark is most pertinent:

> In research writing, the trend is still towards conformity because a majority of

> academics look for recognition through publications in the English-speaking world, where established conventions and standards are observed rather seriously by scientists and other academics in various disciplines.
>
> *[Bhatia, 1993:37]*

On the basis of the foregoing discussion, it can be argued that every genre has a distinctive schema, rhetorical, and textual structure, and if texts can be classified on these bases, the study of genres, particularly written genres, can be very useful for both the teaching and the learning of writing research in academic and professional settings.

2.1.7 The Study of Written Genres: Function

The function of the study of written genres within a discourse community is twofold: first, providing a model for a writer who wishes to write in a genre, and second, predisposing a reader towards what he can or cannot expect from a text. Fowler holds that genres provide positive support to the author:

> Far from inhibiting the author, [the study of] genres are a positive support. They offer room, as one might say, for him to write in (...) to order his experience during composition.... [They operate] as problem-solving models. Instead of a daunting void, they extend a provocatively definite variation. The writer is invited to match experience and form in a specific yet undetermined way.
>
> *[Fowler, 1982:31]*

It is therefore quite understandable why creative writing courses in literature departments throughout the world require the participants to first read, as many as possible, the best exemplars of the genres in which they wish to gain competence as writers. Such apprentice creative writers, through reading enormously, acquire their own individual unconscious concept of the genre(s), which they ultimately try to approximate. As no two individual minds can evolve similar concepts about a literary genre (Is Pope's *Essay on Criticism* a poem?), no two individual writers will ever write in quite the same way. This proves Georges de Buffon's (1707-1788) assertion that "Style is the man himself." Colie (1973) remarks about writing in a genre in the following words:

> (...) though there are generic conventions ... they are also metastable. At the time of writing, an author's generic concept is in one sense historical, in that he look back at models to imitate and to outdo. The works he writes may alter generic possibilities ...

> almost beyond recognition.
>
> *[Colie, 1973:30]*

But to outdo is the prerogative only of geniuses; thus, the generic conventions may be altered only once in a while. Such imitation was explicitly taught in the rhetorical tradition, and apprentice writers were asked to follow models, sometimes blindly:

> Rhetorical education, always a model-following enterprise, increasingly stressed *structures* as well as styles to be imitated in the human letters — epistles, orations, discourses, dialogues, histories, poems — always discoverable to the enthusiastic new man of letters by kind. (original emphasis)
>
> *[Colie, 1973:4]*

According to Thibaudet (as quoted in Fowler 1982:23), "to create in accordance with one genre means to extend this genre." This process is most evident in the realm of literature than any other field. Today, there are thousands of exemplars of literary genres, and new exemplars are being created each day. The process continues and as long as writers imitate and extend these genres, it will continue unabated. And as genres undergo the process of extension, prescriptions for imitation become progressively more detailed and demanding (Fowler, p. 29).

According to Fowler (1982), every genre has distinct generic markers which not only "help to establish (...) an appropriate mental 'set' that allows the work's generic codes to be read" (p. 88) but also prepare the reader's "expectations of genre in a more discriminating way" (p. 98). Todorov sums up the whole argument in the following words:

> It is because genres exist as an institution that they function as "horizons of expectation" for readers and as "models of writing" for authors.... On the one hand, authors write in function of (which does not mean in agreement with) the existing generic system ... On the other hand, readers read in function of the generic system, with which they are familiar ... however, they do not need to be conscious of this system.
>
> *[Todorov, 1990:18-19]*

Apropos of specialised genres, such as the research article, the writer needs to have a thorough knowledge of the genre system. Such genre systems are developed by discourse communities. For a discourse community, genres are important because they help to realise the goals which the discourse community has set for itself. In a way, extension of the genre results in the extension of the discourse community.

2.2 Functional Variation in Discourse

The notion of functional variation in discourse (written and spoken) is based on the observation that "the linguistic behaviour of an individual is by no means uniform" (Reid, 1956). This variability in the linguistic behaviour of individuals generates what Reid terms different ***registers***, the term adopted by the systemists to refer to variation in discourse along the parameters of field, mode and tenor (Halliday, McIntosh and Strevens, 1964; Halliday, 1979, 1985a, 1985b; Gregory and Carroll, 1978). According to Halliday et al., (1964):

> Language varies as its function varies: it differs in different situations. The name given to a variety of language distinguished by use is 'register'.
>
> *[Halliday, McIntosh, & Strevens, 1964:87-89]*

Thus every register has a particular configuration of field, mode and tenor which distinguishes it from any other register. Halliday (1985b) refers to such register variations as "functional variations" — that is, variation according to "use" or "function". An alternative term used by Gregory (1967) is *diatype*.

By whatever name it may be called — functional variation or diatype variation — it is precisely on account of this concept that scientific English is regarded a specific text type. Different scientific texts will, therefore, exhibit striking similarities of structure and tenor that can be discovered by analysing a large sample of such text types. For example, on the basis of tenor as a contextual variable, Huddleston, Hudson, Winter, and Henrici (1968) classified scientific texts as either highly specialised, moderately specialised, or popular level.

2.3 Scientific Text Analysis

Perhaps the greatest influence of the concept of functional variations could be found in the field of English for Specific Purposes (ESP), an influence that gave rise to a whole new branch, English for Science and Technology (EST). Investigators and EST practitioners attempted to characterise the language of science in different ways. Three major approaches can be identified: the ***Register analysis*** (Barber, 1962; Huddleston, 1970; Gopnik, 1972); the ***Grammatical-Rhetorical approach*** (Selinker, Trimble, & Vroman, 1974; Selinker, Trimble, and Trimble, 1978; Trimble, 1985); and the ***genre analysis*** (Swales, 1981, 1985, 1990; Dudley-Evans, 1986, 1987; Hopkins and Dudley-Evans, 1988; Adams-Smith, 1987; Crookes, 1986). The following sections review and discuss these approaches.

2.3.1 Register Theory & Register Analysis

Although register analysis of scientific texts owes its theoretical basis to the concept of register (register theory) as expounded by Halliday, McIntosh and Strevens (1964; and in other subsequent publications), it has concerned itself only with isolating lexico-grammatical features of texts. Its practitioners appear to have lost sight of the basic fundamental of register theory: potential meaning. In register analysis studies, we, therefore, only find frequencies of lexicogrammatical features: numbers and percentages with almost no attempt to relate the occurrence and frequency of such features to potential meaning. The term register is, therefore, not used with its potential implications, as understood in the systemic tradition. "Too often", Robinson (1980:18) notes, "the term register is used to refer just to vocabulary and collocation." She further points out that "the study of the verb and/or noun phrase, even of sentence patterns, or sentence connection is not enough" (p. 19).

The most notable studies, and also the earliest, in this tradition are the ones by Barber (1962) and Huddleston, Hudson, Winter, and Henrici (1968). Barber's is a pioneering work and has been praised for its descriptive techniques, it is nonetheless, criticised for not attempting to provide any explanations for the frequency of a certain grammatical or lexical item. Also his data is too limited (only three texts) to allow useful and valid generalisations. The report by Huddleston *et al.*, (1968) is also not very useful as they do not show how the language of one field of activity is different from that of another (Mackay and Mountford, 1978).

A similar study is that by White (1974). Like Barber, White also performed frequency counting of syntactic features. He can also be criticised exactly on the same grounds: non-representative corpus (laboratory reports, scientific textbooks and general English textbooks); and lack of attempt to characterise frequency of syntactic features. In a later study, White (1975) discovered that a specific feature could not be taken as criterial for one particular register, and that it was the "unique constellation of features rather than any single characteristic" that made one register distinctive from another. He even asserts that "with sufficient data it would be possible to devise a series of register 'specifications', in which typical constellation of features could be specified for each register." However, as Widdowson (1979:55) contends, this 'constellation of syntactic features' may be useful for identifying scientific texts, "it cannot reveal the communicative character of what is written. It cannot of its nature deal with discourse."

Other such studies which rely heavily on statistical counting are the ones by Wingard (1981) and Heslot (1982). The study by Heslot is reviewed in section 2.5.5.3 below.

Strevens (1977), and Candlin, Kirkwood, and Moore (1978) suggest that an important consideration in scientific text analysis is purpose. Even White (1975) acknowledges the existence of such a purpose and refers to it as "the crucial determinant of language form". Similarly, on a more abstract level, Widdowson, (1979:22-23) points out a confusion "between *language* and *a language* and between *form* and *function*", and suggests that emphasis be placed on communicative functions of lexicogrammatical features (potential meaning) rather than linguistic forms.

However, some of the register analysis studies discussed above may be excused on the grounds that they were undertaken with the express purpose of discovering forms that learners would need in particular situations. And as registers have semantic potential, to teach learners a register, one needs first to make an inventory of the grammar and forms through which this potential is realised, and sometimes to identify a sequence in which they could usefully be taught (Jean Ure, pers. comm.).

In short, such quantitative studies may be regarded as meaningless unless the frequency of a syntactic or lexical item is also discussed in relation to its particular semantic potential and in relation to the frequency of another comparable syntactic or lexical item. Bhatia (1993) holds that:

> Analysis of varieties or registers on their own reveal very little about the true nature of genres and about the way social purposes are accomplished in an through them in settings in which they are used.
>
> *[Bhatia, 1993:18]*

Widdowson (1979) stresses the need for a 'qualitative' approach to register that should include a consideration of communicative competence, purpose, and role performance. What Widdowson advocates may be termed *genre analysis* (see section 2.3.3 below).

2.3.2 Grammatical-Rhetorical Approach

The Grammatical-Rhetorical approach (henceforth GR approach) was developed, it appears, in direct response to the criticism levelled at the Register analysis approach. Its proponents (Lackstrom, Selinker and Trimble, 1972; Selinker, Trimble and Vroman, 1974; Lackstrom, 1978; Trimble, 1985), arguing for form and function correlation, hold that grammatical choices cannot be discussed without a consideration of their rhetorical function and the subject matter. This approach is modelled on three rhetorical concepts:

1. The nature of the EST paragraph
2. The rhetorical techniques most frequently used in EST
3. The rhetorical features most frequently found in EST

The GR approach is radically different from Register analysis in that it offers rhetorical explanation of the distinct features of scientific texts. Ure (pers. comm.) sees the difference between a rhetorical approach and register analysis in terms of how the two treat meanings in texts: whereas a rhetorical approach looks at specific texts, and ***instantial meanings***, deriving from the function of each grammatical choice in context, register analysis is interested in ***potential meanings***, derived from recurring choices characterising text types. However, the GR approach suffers from a few very obvious limitations. First and foremost, the rationale that underlies this approach was based on a very restricted database: scientific textbooks in Engineering and 'supplementary materials'. Scientific textbooks are just one form of scientific texts, and the nature of the 'supplementary materials' was not defined. Second, the GR model was specifically geared to help the non-native learner to read his/her textbooks more efficiently. The model, as such, does not account for the organisation of information in written texts.

From the perspective of this study, the GR approach is important in that it did attempt to study the grammatico-rhetorical features of the research article. For example, West (1980) studied the frequency of *that*-nominals in 15 biological science articles. He discovered that the number of *that*-nominals varied significantly across the rhetorical divisions of the research article. However, the study appears to be more in the tradition of Register analysis than in that of the GR approach, for West only compared the frequency of *that*-nominals across the divisions of the RAs without ever attempting to consider what prompts a writer to use or not to use *that*-nominals. It is more important to discover what entails the lesser or greater use of such lexicogrammatical features across the divisions of the research articles than only to count their frequency.

It is the genre analysis approach that answers such questions. It not only deals with segments of texts but also with the overall organisation of information in texts. The following sections discuss genre analysis in some detail.

2.3.3 The Genre Analysis Approach

It should be noted that very few of the studies reviewed above distinguished register from genre. And according to Bhatia (1993:17), these studies tend to treat experimental research articles, excerpts from science textbooks, and lab reports as legitimate instances of scientific English. For *genre analysis*, this distinction is paramount. The emergence of *genre analysis* (as popularised by Swales, 1981-1990) can be briefly described as a shift in interest from *micro-textual* analyses — 'investigations into sentence length, voice, vocabulary and so on' — to 'an interest in providing a deeper or multi-layered textual account such as assessing rhetorical purposes, unpacking information structures and accounting for syntactic and lexical choices' — in short, to an interest in *macro-textual* analyses. These two approaches, register analysis and genre analysis, differ in terms of their underlying rationale: whereas register analysis is concerned with finding out what forms to teach and how to present them to *beginners* (ESP students who do not know the language), genre analysis is concerned with sensitising already proficient students (ESP students who know the language) to the use of appropriate forms to meet the demands of particular genres (Jean Ure, pers. comm.). Moreover, genre analysis is distinct in that it has both sociological and psycholinguistic aspects: whereas the sociological aspect "focuses on the conventional and often standardized features of genre construction" thereby making "it possible for the analyst to understand how a particular genre defines, organizes and finally communicates social reality" (Bhatia, 1993:18), the psycholinguistic aspect "reveals the cognitive structuring, typical of particular areas of enquiry" (*op cit.*:19). In short, genre analysis is concerned with the 'communicative character' of discourse:

> Work in ESP was, by the middle eighties, not merely interested in characterizing linguistic *effects*; it was also concerned to seek out the *determinants* of those effects. It thus, of its nature, deals with the 'communicative character' of discourse.
>
> *[Swales 1990:4; original emphasis]*

Some of the studies of scientific texts (reviewed in section 2.3.1 above) laboured under the misleading impression that there existed *special* languages and that the purpose of ESP research was to analyse the lexical and syntactical features of those special languages. The reference to register in some of the studies reviewed above (section 2.3.1) seem to imply that scientific text analysis was the study of special languages (Robinson, 1980:16). It has only recently been realised that the English used in ESP text-types is in no way special, except the jargon, and that it is the purpose to which English is put in these texts that is *special*. Moreover, it is quite surprising that studies purporting to be following the register theory of the systemists should have totally ignored such important determinants as "interlocutors' communicative roles and intentions, their role relationship, their code and knowledge repertoires, and ... the general conventions of communicative social activity" (Weber, 1982:221). We know that:

> (...) the determining factors in the make-up of texts are not linguistic in origin as the formal properties of the linguistic system do not enable us to explain how texts are produced and structured. Instead the control is contextual: texts are fundamentally the product of a non-verbal social event whose primary mode of unfolding is, however, of a linguistic nature.
>
> *[Weber, 1982:221]*

Accordingly, it is "now widely argued that LSP research must primarily be concerned with the classification and analysis of *special purpose* text-types" (*op cit.*:219, emphasis added). This argument is based on the fact that the communicative behaviour of the members of a particular discourse community is regulated and determined by pre-established norms and patterns (*op. cit.*:222) which result in text-types that share a great deal in common:

> People engaging in standardized communication forms established through social convention in a way endorse conventional contracts for the production of standardized texts. [We know that] recurrent and conventionalized forms of communication do not produce an infinite number of distinct texts but that standardized classes of texts are generated which are characterized by a high degree of uniformity regarding their form, structure, and function.
>
> *[Weber, 1982:222-223]*

Weber further argues that the participants in a standardised discourse community "usually carry rather detailed cognitive images of the required text types and their typical textual features" (p. 223). The scientific research article is one such type of text, "a gargantuan genre — in the printed medium unrivaled in number of exemplars" as in no other genre 'the strength of genre-specific conventions' is more manifest. (Swales 1990:95). As Knorr-Certina (1981:106) remarks: "the published paper is a multilayered hybrid *co-produced* by the authors *and* by members of the audience to which it is directed" (original emphasis). Thus, as Ard (1985:16) puts it, "the scientific community, rather than the individual scientist, provides the *authority* for the rhetoric. The individual scientist becomes authoritative only by following the tradition" (original emphasis). These constraints, as a corollary, lead "to a degree of standardization which suggests that experimental-research papers may share a common basic structure or schema, or employ common units of discourse" (Crookes 1986:58) which may be identifiable across RAs in various disciplines.

This realisation introduced the concept of genre as a viable description of 'the common basic structure' of discourse. *Genre Analysis* is thus concerned with discovering that common macrostructure or schema of text-types that belong to a genre. According to Swales (1990):

> [Genre analysis] offers, among other things, a way of studying discourse development over time that is detachable from an analysis of an individual event of an individual author; it also suggests, by way of comparing rhetorical similarities and differences, a potential method of establishing the genre-membership or otherwise of a particular text.
>
> *[Swales, 1990:43]*

Genre analysis is thus a very important development in the field of EAP, particularly, with regard to the experimental research article (RA). Genre analysis has not only provided insights into the schematic structure and rhetorical features of the RA, but has also suggested new ways to teach the writing of the RA to both students and professionals belonging to a discourse community.

2.4 RAs in Academic Discourse Communities

Swales adopts the concept of discourse community (see section 2.1.4 above) to emphasise the importance of the scientific research article. An obvious example of a discourse community would be the group of people who are professionals or would-be professionals of an academic discipline.

Discussing the role of discourse in a discourse community, Herzberg (1986:1) writes: "discourse is a means of maintaining and extending the group's knowledge and of initiating new members into the group and that discourse is epistemic or constitutive of the group's knowledge." As already discussed, discourse communities have pre-established norms and patterns which regulate the way their members communicate. The scientific RA is, undoubtedly, the greatest exemplar of this behaviour. It is used for 'information exchange' almost exclusively. Thus, it is the RA which bears the full thrust of the epistemic objectives of a particular discourse community.

2.4.1 Types of Research Articles

Two basic types of research articles published in journals have been identified: the theoretical research paper (TRP) and the experimental research article (RA) (Morris 1966:204). To this we may add a third type, the review paper (RP), which is recognised by some as an important and separate type (e.g., Paterson 1961).

Of the three, it is the RA which has been the focus of genre-based analysis. I can think of only one reason for the prominence given to the RA: this type tends to have a basic genre structure while the other two types are more fluid. The hypothetico-deductive scientific method that appears to be the hallmark of the experimental RA gives this type of RA a standard basic structure or schema (Crooks, 1986:58).

The experimental RAs across many a discipline have been found to share a basic structure that is often referred to as the IMRD structure (Introduction-Method-Results-Discussion). However, it is quite difficult for TRPs and RPs to have common, standard subdivisions across various disciplines or even within the same discipline. Attempts to define labels for the different sections of TRPs and RPs can never go beyond the traditional three part division into introduction, body and conclusion.

Hartley and Knapper (mimeographed & undated, quoted by Becher, 1987) report that the scholars in the arts disciplines differ markedly from their counterparts in science disciplines in structuring their argument. According to them, "Artists appear to go more for the argument, working from the 'top down', as it were, whereas scientists seem more inclined to write individual components and work from the 'bottom up'."

Even scientists might behave like the artists when writing TRPs and RPs. Here, I have in mind the state-of-the-art papers published regularly in *Language Teaching Abstracts* and other such papers as "Twenty-five years of contrastive rhetoric: Text analysis and writing pedagogies" (Leki, 1991). The points raised so far may thus be summarised as follows:

1. That RAs tend to have a standard form and style concomitant of the hypothetico-deductive scientific method with standard labels for the subsections such as Introduction, Method, Results, Discussion (IMRD). The argument of an RA may be developed from 'bottom up'. Not only may the sections be written in any order, they may even be read in any order.
2. That TRPs and RPs lack a standard form or structure. The main thrust falls on the argument which is mostly developed from 'top down'. The sections, if any, may be variously labelled. And, more importantly, the reader would seem to have no choice but to begin at the beginning and work his/her way through to the end to understand the argument.

In the modern scientific world, the RA is considered to be more important and prestigious than the other two. According to Bazerman:

> The experimental report seems central to many conceptions of the sciences as empirical inquiry. The experimental report has developed as a favored solution of the problem of how to present empirical experience as more than brute fact, as a mediated statement of inquiry and knowledge.
>
> *[Bazerman, 1988:7]*

And again, "Although many kinds of communication pass within scientific communities, experimental reports are close to the heart of the accountability process, for experimental reports present primary account of empirical experience" (*op. cit.*:62). It is thus this type of the scientific communication which is the focus of the sections to follow. So let us now turn to see what genre analysis has so far contributed 'to our understanding of the cognitive structuring of information' in the research article genre.

2.5 The Research Article Genre

It is generally agreed that the logical structure of the research article is best represented by the IMRD pattern. Hill, Soppelsa & West (1982) were probably the first to describe this structure in detail. The Hill *et al.*, (1982) model closely resembles the shape of an hour-glass. The three divisions of the model, *introduction*, *procedure*, and *discussion*, closely correspond to the three rhetorical divisions recognised in western writing: the beginning, the middle, the ending. According to Hill *et al.*, (1982):

> What separates the introduction, procedure, and discussion sections from each other

> are their functions within the research paper. The introduction provides a transition from the larger academic field to the particular experiment. The procedure section describes the particular experiment. The discussion, like the introduction, is a transition too, but its purpose is to guide the reader from the particular experiment back to the larger academic area.
>
> *[Hill, Soppelsa and West, 1982:334]*

Thus the movement within these sections can be described as from general to particular in introduction, narrow in procedure, and from particular to general in discussion.

In order to corroborate the validity of their model, Hill *et al.*, (1982) analysed a research article from psychology. They broke down the five sentence introduction as follows: the first sentence establishes the general field of inquiry; the second describes a particular experiment used in the field; the third indicates a need for the present study by pointing out a limitation of that particular experiment; and the last two present the hypothesis for the study undertaken. Their analysis corroborates their description of the movement in introduction as "the transition from the general field or context of the experiment to the specific experiment by describing an inadequacy or inaccuracy in previous research which motivates the present experiment" (p. 335).

Hill *et al.*, (1982) identified two distinct steps in the procedure section collecting the data and manipulating the data. Hence they divide the procedure section into two subsections: Method and Results. Based on the analysis of their sample RA, they argue that "The methods section is a chronologically ordered section, a step-by-step description of the process used to obtain the data, arranged according to the time sequence followed" (p. 336). They were able to identify eight steps in the eleven sentence methods section of their sample RA. Two major parts were identified in the Results section: the first described the manipulation of data, statistical analyses and tables, etc., while the second reported the empirical results.

Hill *et al.*, (1982) describe the discussion section as the mirror image of the introduction section in that it moves in opposite direction to introduction, that is, from particular to general. This movement is described as such: "It moves from the solution of the problem that motivated the study to the implications of the solution for the larger field ..." (p. 337). Though Hill *et al.*, (1982) do not specifically propose steps or moves or some kind of ordering pattern for the discussion section as they do for the other sections, they do discuss the structure of the section sentence-wise which may be summarised as follows:

> **Move 1:** The research question posed in the introduction is answered based on the empirical findings reported in the Results section.
>
> **Move 2:** Reasons are suggested for the difference(s) between the previous experiment or study and the present one.
>
> **Move 3:** The results are related to the larger field.
>
> **Move 4:** Limitations of the study may be pointed out, which provide areas for further research.

As these generalisations are based on only one paper, it will be later seen whether they will hold their own against other rigorous studies.

Investigators have also attempted to describe the structure of the individual sections of the research article. Zappen (1983), following Toulmin (1972), suggests that the RA introduction be viewed as 'encapsulated problem-solution text'. Zappen argues that it in the introduction that "the researcher addresses the goals, current capacities, problems, and criteria of evaluation that derive from and operate within the discipline" (p. 130). For Zappen, then, the introduction has five steps: a description of *goal*, and *current capacity*, an indication of the *problem*, and its possible *solution*, and a statement of the *criteria of evaluation*. Zappen illustrates this with the help of a simple and short engineering introduction. Commenting on Zappen's five part division, Swales writes:

> (...) while the five-part rhetorical division is itself plausible, the labelling of these divisions suggests a rather flat and certainly sunny world in which the empirical repertoire of logic, objectivity and reason strongly predominates.
>
> *[Swales, 1990:138]*

What Swales means is that the divisions are not always that straightforward. For example, Adams Smith (1987) found that 'the medical RAs she examined either failed to contain a recognisable *problem* or tended not to foreground it'. What Swales is suggesting is that the Zappen's labels needs to be replaced by labels which can be identified across RAs from various disciplines. This proposal is in accord with Swales' own attempt (1981) to prescribe rhetorical moves that make-up the RA introduction. What prompted Swales, in the first instance, to embark upon such an investigation was his dissatisfaction with the courses dealing with Report and Project Writing, particularly when it came to teaching how to write an introduction. Swales (1984) himself comments: "(...) over the years I have become particularly dissatisfied with the prescriptive and under-researched character of the Units [in EAP courses] dealing with the writing of *Introductions*" despite the fact that "Writing an introduction to an article is obviously a more specialized activity ..." (p. 77). Investigation into the rhetorical pattern of introduction becomes all the more important if we accept that "nearly all writers have more difficulty with getting started on a piece of academic writing than with the latter sections" (*op. cit.*:78). Swales puts forward the following reasons for his undertaking the analysis of RA introductions that he embarked upon in 1981:

> I therefore feel there is a strong pedagogical justification for attempting to develop our understanding of the mechanics of writing the introduction of journal articles, because I assume that many overseas postgraduates, researchers and academics are facing up to the problems of writing articles in English and can be supposed ... to be having particular difficulty with the opening paragraphs.
>
> *[Swales, 1984:78]*

2.5.1 The Introduction Section

Swales analysed 48 RA introductions, 16 each from three areas: the 'hard' sciences, the biology/medicine field, and the social sciences (education, management and linguistics). On the basis of his analysis, he proposed the following broadest outline for the RA introduction:

Since its first appearance in 1981, the 4-Move model has generated a lot of interest in the genre of the research article. Consequently, a number of investigators have attempted to validate the model across various disciplines. Cooper (1985) was probably the first to apply this model to 15 introductions from the publications of the Institute of Electrical and Electronic Engineering (IEEE). She discovered that the Swalesian model did not fit completely the macrostructure of her introductions. Three of her introductions did not have a Move 2, while the same number did not have a Move 3. Moreover, seven of her introductions had a totally different sequence. Thus she concluded that her corpus had "a different discourse structure than that proposed by Swales' model" (p. 36). This led Cooper to hypothesise that the model is appropriate for those fields only which have an established and mature research tradition. As electronics is still a developing field, its RAs are mostly aberrant and atypical.

Move 1	**Establishing the Field**
	a) by asserting significance
or	b) by stating current knowledge
Move 2	**Summarising Previous Research**
	a) using a *strong* author-orientation
and/or	b) using a *weak* author-orientation
and/or	c) using a *subject* orientation
Move 3	**Preparing for Present Research**
	a) by indicating gap in previous research
or	b) by raising a question about previous research
Move 4	**Introducing the Present Research**
	a) by stating the purpose
or	b) by outlining present research

[Swales, 1981; 1983:192-93]

Though Swales's work is rigorous and is based on an adequate corpus, "the research lacks empirical validation" (Crookes 1986:61). This is a serious criticism, but Swales (1981:14) himself recognises it: "I am open to the charge that my unsubstantiated and ill-defined terminological labels ... are little more than a reflection of my own perceptual predisposition."

Crookes selected his corpus consisting of 24 introductions from the same fields as Swales'. He found that the sequence 1-2-3-4 occurred only in five introductions. The structure 2-4 also occurred in five (but his Table on page 64 lists only four such RAs). Moreover, seven of the short introductions did not have a Move 3, and eight of the long ones had move cycles 1-2-3-2-3-2-3-4. Commenting on his results, Crookes states:

> It may be tentatively concluded that results are consistent with the idea that four basic units of discourse occur in scientific experimental-article introductions. In some shorter introductions, there is a tendency to find the simple four move schema posited by Swales, but this is by no means the only possibility.
>
> *[Crookes, 1986:65]*

In a more rigorous and notable study, Hughes (1989) analysed 20 introductions from computer journal articles. Her analysis showed that the majority of her introductions did not readily fit into the 4-Move pattern. Only four of her introductions had easily identifiable four moves occurring in the assigned sequence. She also found between Moves 3 & 4 blocks of text giving background information. She observed the repetition of Moves 2 & 3 in one introduction and that of only Move 2 in another. She also noted variation in the order of the moves. While eighteen of her introductions began with Move 1 and concluded with Move 4, three began with Move 4. One of these had a further Move 4 giving details and structure of the present research.

A feature hitherto unreported by others was that she discovered blocks of text occurring in between various moves which could not be ascribed to any move. These blocks fulfilled the function of giving background information or technical specifications, etc.

In a very recent study, Dudley-Evans & Henderson (1990) analysed 22 introductions from the *Economics Journal*. They divided their corpus into three time periods: 1891 to 1925; 1935 to 1957; 1961 to 1980. Introductions from the first period showed very few features identified by Swales. Most introductions from the second period were found to have the Swalesian Moves, but they did not exhibit all the features of the 4-Move model. It was in the third period that introductions were found to consistently follow the 4-Move pattern. Moreover, the introductions from this period were found to be much longer and had clearly author-labelled sections (pp. 75-76).

These findings (Dudley-Evans & Henderson) reveal that the macrostructure of a particular genre evolves over a period of time and that until it establishes a tradition and a research convention, it remains in constant flux. This evolution is always directed towards establishing a research macrostructure. This supports the views adopted by Cooper (1985) and Hughes (1989) that article introductions in fields which are still undergoing the process of development and which are yet to mature do not follow the Swalesian model.

One main problem reported in most of these studies has been the difficulty in separating Move 1 (*Establishing the Field*) and Move 2 (*Summarising Previous Research*). Moreover, Move 2 tended to occur throughout the introductions which disrupted the sequence of the moves causing the introductions not to fit the model.

In the light of these reports, Swales (1990) has now modified his earlier model. The new model consists of only three moves. Move 1 of the new model combines the first two moves of the earlier model. Moreover, he has also given his modified version a proper name, the *CARS* model, acronym for *Create a Research Space*. Swales has been able to show that the *CARS* model is equally viable for short and long introductions (pp. 142-43). Regarding this change, Bhatia (1993) remarks:

> Clearly, Swales (1990) has been able to avoid the difficulty of distinguishing the first two moves in his earlier model. However, inadvertently perhaps, he has created a more serious problem by combining the two.
>
> *[Bhatia, 1993:85]*

Bhatia basis his argument on the fact that literature review (LR) has a well-established place in RAs: that no research publication can be complete without an adequate review of past literature. He believes that LR has "conventionally acquired an independent status in research writing." Thus, he argues for "finding adequate linguistic criteria to separate them."

However, the very fact that LR has a well-established status in research writing makes it least likely to be left out by even novice research writers. LR is a very conspicuous feature of all research writing. It, therefore, does not need to be given an independent status. There are three main needs that a writer must address in the introduction:

1. the need to re-establish in the eyes of the discourse community the significance of the research field itself;

2. the need to 'situate' the actual research in terms of that significance; and
3. the need to show how this niche in the wider ecosystem will be occupied and defended.

[Swales, 1990:142]

These three needs correspond to the three Moves that comprise the *CARS* model which is reproduced below (Fig. 3). I have assigned decimal numbers to the steps for ease of reference in the discussion that follows. Thus Step 3.3 would mean STEP 3 within MOVE 3.

MOVE 1:	**Establishing a Territory**
	Step 1.1 Claiming centrality
and/or	Step 1.2 Making a topic generalisation
and/or	Step 1.3 Review of previous research
MOVE 2:	**Establishing a Niche**
	Step 2.1a Counter claiming
or	Step 2.1b Indicating a gap
or	Step 2.1c Question raising
or	Step 2.1d Continuing a tradition
MOVE 3:	**Occupying the Niche**
	Step 3.1a Outlining purposes
or	Step 3.1b Announcing present research
	Step 3.2 Announcing principal findings
	Step 3.3 Indicating structure of RA

Figure 3. A *CARS* model for article introductions (Swales 1990:141).

What follows is a summary of Swales' observations regarding the Moves and the Steps that make up the *CARS* model (pp. 144-161).

MOVE 1: Swales views centrality claims (Step 1.1) as "appeals to the discourse community whereby the members are asked to accept that the research about to be reported is part of a lively, significant or well-established research area" (p. 144). Typically, Step 1.1s are achieved in a single sentence at the beginning of the introduction, but sometimes may extend over two or more sentences. Centrality claims are achieved in a number of ways:

a) By claiming *interest* ('Recently, there has been a spat of interest in how to ...')
b) By claiming *importance* ('Knowledge of ... has a great importance for ...')
c) By referring to the classic, favourite, or central problem, issue, etc. ('The time development ... is a classic problem in fluid mechanics.')
d) By claiming that other investigators are active in the area ('Many investigators have recently turned to ...')

[For details & more examples see Swales, 1990:144]

Step 1.2 statements are general in nature which can take a number of forms, the most common being about *knowledge* or *practice* ('There is now much evidence to support the hypothesis that ...'), or *phenomena* ('An elaborate system of ... is found in the ...'). Swales notes that "there is strong tendency for *phenomenon* topic generalizations in particular to establish territory by emphasizing the frequency and complexity of the data ..." (p. 146).

The function of Step 1.3 in establishing the territory is to review one or more items relevant to the study. Minimal reference has been found to be obligatory. However, there may be no references to previous work if the discipline is still evolving and has little accumulated research tradition (for example, computer science as reported by Cooper 1985). Apropos of the need to relate *what has been found* (or claimed) with *who has found it* (or claimed it), Swales mentions three elements: "*specification* (in varying degrees of detail) of previous findings, an *attribution* to the research workers who published those results, and a *stance* towards the findings themselves" (p. 148). These will be discussed in the next section at the appropriate place.

MOVE 2: A common practice of initiating Move 2s is by using an 'adversative sentence-connector' of which *however* is the most common; but *nevertheless*, *yet*, *unfortunately* and *but* are also common. Gaps in the previous work are signalled lexically in the verb (*suffer; is limited to*) or in the adjective phrase (*time consuming; expensive; not sufficiently accurate*) or verb negation (*cannot treat*).

In a 'quick and dirty' survey of 100 Move 2s from physics, geology, psychology and composition, Swales was able to discover the following eight categories in order of decreasing frequency:

a) *Negative or quasi-negative quantifiers* (28 instances). {no, little, none (of), few/very few, neither ... nor}
b) *Lexical negation* (26 instances). {fail, lack, overlook; inconclusive, complex, misleading, elusive, scarce, limited, questionable; failure, limitation, without regard for}
c) *Negation in the verbal phrase* (16 instances). {not, rarely, ill}
d) *Direct/Indirect question* (8 instances). {E.g., 'A question remains whether ...'}
e) *Expressed needs/desires/interests* (8 instances). {E.g., 'The differences need to be analysed ...'; 'It is desirable to ...'; 'It is of interest to ...}'
f) *Logical conclusions* (6 instances). {must, seem/appear, one would intuitively expect}
g) *Contrastive comment* (6 instances). {Mostly '... rather than ...'}
h) *Problem raising* (2 instances). {E.g. '... presents a problem ...'; 'The key problem ...'}

[for details see Swales, 1990:155-56]

Swales notes that categories (e) and (f) seem to be chosen when the challenge to the previous research is weaker (p. 156). In such cases the most common sentence connector is *therefore* rather than *however*. Commenting on the cyclic nature of Move 2 (recurrence of Step 1.3 and Move 2), as reported by various investigators (Cooper 1985; Crookes 1986; Hopkins & Dudley-Evans 1988), Swales posits that "if the relevant research tradition is viewed as linear and cumulative, then a composite [chunked] arrangement may work well" (p. 158). Else a cyclic pattern may be preferred.

MOVE 3: The purpose of Move 3 is to occupy the niche established with the rhetorical devices used in Move 2. According to Swales, "Whenever a Move 2 occurs ... the ensuing Move 3 variously offers to substantiate the particular counter-claim that has been made, fill the created gap, answer the specific question or continue the rhetorically-established tradition" (p.159). The obligatory Step 3.1a or Step 3.1b make a 'kind of promissory statement' mostly introduced by a deictic reference such as *In this paper* ... It is typical for the deictic reference to occur early. Swales holds that "apprentice writers, both NS and NNS, are more prone to delay the Move 3 signal — and by doing so likely to create uncertainty in the reader" (p. 160).

Swales (p. 160) further observes that in these opening Steps, the tense is restricted to the present if the deictic reference is to the *genre* (paper, report, etc.). However, if a noun such as *investigation*, *study*, or *experiment* is used, the writer may choose between present or past.

Usually, the introductions end with Step 3.1, but it may be followed with a 'summary announcement' of the principal findings (Step 3.3). The writer may also choose to indicate the structure of the RA in statements such as 'This paper is structured as follows ...' etc. Cooper's (1985) specialist informants (computer scientists) both expected and welcomed such indication. But in most other fields this feature is rare (Swales p. 161).

Jingfu (1987) was the first to test the validity of an earlier version of the *CARS* model, not yet fully developed and published. She applied the 3-Move pattern to the introductions of ten chemical engineering RAs. All her introductions, except one which has the pattern 1-3-2, contained the three moves in the assigned order (p. 93). Her results reveal that the 3-Move pattern has a better fit than the earlier 4-Move model. As she used a much simpler form of the *CARS* model, it is better to reproduce it for comparison:

Move 1:	Handling Previous Research
	(Option A: Appeal to the readership)
	(Option B: Topic generalisation
Move 2:	Preparing for Present Research
Move 3:	Introducing Present Research

[Jingfu, 1987:85]

In an earlier attempt (Rahman, 1991) to validate the *CARS* model, I analysed 15 RA introductions from the *Journal of Structural Geology*. It was found that only nine introductions neatly fitted into the *CARS* move pattern. The remaining six introductions were found to have cyclicity of one or more moves, particularly, Step 1.3, *Review of Previous Research*. This was mainly due to the reason that literature review takes different forms:

> [...] the authors ... use literature review for various purposes, such as for providing background information to establish a territory, for assessing the models available for a study, for verifying their own findings, and for describing the experiments and field techniques available for and used in the study.
>
> *[Rahman, 1991:44]*

These findings were consistent with those reported by Lopez (1982), Bley-Vroman and Selinker (1984), Crookes (1986), Jacoby (1986) and Hughes (1989) with regard to Swales's earlier model. Furthermore, I also discovered that literature reviews appearing in different positions in the introductions were not similar in nature (see pp. 45-46), that they had different *discoursal values*, and that it might be possible to refer to them by different names, such as:

1. *background review* to support [and further sharpen] the topic generalised in Step 1.2;
2. *foreground review* to justify and support the claim(s) made in Move 2; and
3. *annotating review* (if any) in the final move to compare or contrast the findings (if reported) OR to comment on the experiment(s) or field techniques used.

   [Rahman, 1991:57]

This suggestion of mine receives ample support from Bhatia (1993) who argues that:

> Like any other feature of linguistic form, citations can also be assigned different discoursal values, depending upon where they occur and what communicative purpose they serve.
>
> *[Bhatia, 1993:87]*

It will be seen that the discussion section also contains similar literature reviews, fulfilling various purposes.

2.5.2 The Method Section

The Method section, according to Hill et al., (1982:336), "is a chronologically ordered section, a step-by-step description of the process used to obtain the data, arranged according to the time sequence followed." They discovered eight steps in the method section of the paper they studied. However, Swales has found that this is not always the case:

> (...) the Method sections of RA often seem increasingly not to be 'reports' in any narrow sense; rather they are highly abstracted reformulations of final outcomes in which an enormous amount is taken for granted.
>
> *[Swales, 1990:120-21]*

Thus, the purpose of the Method section is not to permit replication. The Method section, most often appears to be a 'listing of procedural formulae', lacking in all coherence. But, as Bruce (1983:8) points out, "the coherence is, of course, supplied by the shared knowledge of these investigative procedures, and their likely sequence, that the reader brings to the text."

Method sections mostly have been found to be much more variable and indeterminate in structure. Thus Swales (1990:168) suggests that a different type of paragraph needs to be established for Method which might be called *broken linear*, because in "many Method paragraphs the sentences are like islands in a string, which only those with specialist knowledge and experience can easily jump across from one to the next" (op. cit.:168). However, Swales (p. 169) is able to discover that some Method sections do have a replicable 'step-by-step' description "massively supported by anaphoric reference and lexical repetitions, [which] produces the kind of explicitness that we associate with standard academic description." But this is mainly true of the hard sciences.

2.5.3 The Results & Discussion Section

The structure of the last two RA sections is largely unestablished. These are being discussed under one heading as they often combined occur as one section. According to Swales (1990:170), "our present state of knowledge about the last two elements in IMRD pattern is, regrettably, largely restricted to an exploratory rather than hypothesis-testing stage." Also, the closing sections of the RA are sometimes differently labelled. Thus, one may find Conclusion, Implications or Applications to be the closing section.

However, Belanger (1982:1) was able to show that "the structure of the discussion section is closely correlated to both the number and kind of research questions posed in the introduction section of the paper." He proposes that each research question (RQ) is passed through 'a cycle':

1. *Summarising results* and stating conclusion with reference to previous research;
2. *What research suggests* with reference to previous research and/or to the current work;
3. *Further questions* sometimes with possible explanations and sometimes with reference.

[Belanger, 1982:1]

These three elements may not be always present, but whenever they are, they follow the order proposed above. According to Swales (1990:173), 'Discussions, in strict contrast to Introductions, move during a cycle in an 'inside-out' direction; they move from stating the results themselves to placing them within the established literature, to review their general significance." Hopkins & Dudley-Evans (1988) suggest the following 11-Moves for the discussion section:

1. Background Information.
2. Statement of Result (S.O.R.)
3. (Un)expected Outcome
4. Reference to Previous Research (Comparison)
5. Explanation of Unsatisfactory Result (reasons)
6. Exemplification
7. Deduction (claim about generalisability)
8. Hypothesis (general claim)
9. Reference to Previous Research (Support)
10. Recommendation (further research)
11. Justification (justifying recommended further work)

[Hopkins and Dudley-Evans, 1988:118]

Hopkins and Dudley-Evans discovered three cycles in their corpus in which the moves occur in the same order. However, I believe that the model is very loose. It needs to be refined. I guess that the number of Moves can be easily reduced to three by reducing the status of many of the moves to steps as in the CARS model.

Adams Smith (1984:30) refers to Calnan and Barabas (1973) who seem to have suggested a pattern for the discussion sections in their book, *Writing medical papers: A practical guide*. A pattern could be retrieved as follows:

1. Explanation/Interpretation: Methods explained and results interpreted;
2. Disputation: Results related to the general body of knowledge of the discipline and the claims of others argued;
3. Disquisition: Implications considered, and author's opinion, philosophy, or theory expressed;
4. Recommendations: More effective procedures, further research, etc.

[see Adams Smith, 1984:30]

However, no model for the discussion section has so far received such wide acclaim as the *CARS model* for RA introductions. All these models have much in common, but none holds one's attention for very long.

2.5.4 The Abstract

And finally the Abstract. It is generally assumed that if a non-native speaker of English can write a research article, he can also write the abstract. Hence, there is a dearth of handbooks or manuals that offer specific help in this respect to the non-native writer (Swales p. 179). In some non-native situations, such as is Spain, the scientists are required to submit abstracts in English even if the research articles are written in L1 (*ibid.*).

The abstract is an important section of the RA as it is 'at the same time both front matter and summary matter.' The abstract is intended to provide "the reader with a brief preview of [the] study based on information from the other sections of the report" (Weissberg & Buker 1990:184). Swales (p. 179) describes the relationship between the abstract and the RA proper as that of distillation. Graetz (1985) has proposed a structure for the abstract consisting of four parts **Problem-Method-Results-Conclusions**. However, Swales, thinking in terms of his Move/Step paradigm, points out that a number of Graetz's abstracts opened with either Move 1 or Move 3. He further suggests that "most abstracts reflect the IMRD pattern of the RA itself, allotting a sentence or two for each section."

Weissberg & Buker (p. 185) suggest a five-part division for a typical abstract: Background, Purpose, Method, Results, and Conclusion. They suggest that some of the elements in the abstract can be eliminated or combined in order to reduce the length of the abstract which they term as the "Reduced Abstract". In such an abstract, the background information is usually not included, and the information about purpose and method is presented first, followed by a summary of the most important results. A statement of conclusion, in this case, becomes optional.

In a very recent study, Salager-Meyer (1992) carried out a genre-specific discourse study and move analysis of 84 medical abstracts for text and modality distribution. The corpus was drawn from three major medical text types: research papers, case reports, and review articles. As the last two are not relevant to our immediate purpose, results for the same are ignored. As for modals, *may* was found to have the highest frequency, almost equal to the occurrences of *should*, *could*, and *might* combined. *Can* was found to have the lowest frequency. The highest occurrence of *may* in scientific writing is attributed to its greater hedging possibilities than the other modals. It is used "when the authors are quite confident of their findings and when they want to indicate a high degree of probability" (Kibui 1988:11; as quoted by Salager-Meyer p. 105). *May* is thus described as the 'conclusion modal marker', and *should* as 'the recommendation modal exponent'. As the result move presents "hard facts" or the most salient and striking results, this section is relatively unhedged.

As for tense distribution, the most frequently used tenses were the past, present, and present perfect in decreasing order of frequency which is in agreement with Heslot (1982). She also found tense variation in the rhetorical divisions of the abstract which corroborates other researchers' findings that "different tenses are exploited for different functions and that the choice of tense does not merely depend on temporal considerations" (p. 101). Her results are summarised as follows:

1. The past passive indicates the sequence of procedures in the actual research that is being reported (obligatory constraint).
2. The past passive is used in the results section in making statements about the likely significance of the findings (obligatory constraint).
3. In the purpose move, the choice of tense (past or present) is basically a rhetorical or strategic choice rather than obligatory constraint.
4. The present tense is used when the authors wish to emphasize the relevance of their own study and to enhance its generizability.
5. The conclusion and recommendation show a high frequency of the present.

6. The present perfect (along with the present) frequently appears in the statement-of-the-problem move.

In short, the abstract shows a striking resemblance to the research article proper in terms of choice of tense, modals, and voice. Salager-Meyer provides a wealth of useful information in the appendices to her study.

At the end of the day, we do not seem to have a complete picture of the macrostructure of the RA. Nonetheless the emerging "picture suggests that there are certain characteristics of RA which, by and large, tend to occur and recur in samples drawn from an extensive range of disciplines" (Swales 1990:174-75). However, it is still doubtful whether these similar characteristics would give rise to what Widdowson (1983) calls 'macrogenre'. Moreover, there are variations in the structure of RA across various disciplines and in the degree of standardisation of the RA within a discipline which cause further problems. This does not, however, render such attempts invaluable; rather, every new study is a giant step towards a macro-configuration of the experimental research article genre.

2.5.5 Linguistic Features of the RA

2.5.5.1 Citation and Reporting

Swales (p. 148) introduces a distinction between *integral* and *non-integral* citations, the former being of the type in which the name of the author cited functions as some sentence element (subject, passive agent, as part of the possessive noun phrase, or as 'disjunct of reporting'), and the latter in which the name of the author occurs in the parenthesis. Moreover, integral and non-integral citations may be either *reporting* or *non-reporting*: reporting if a verb (such as, *show*, *establish*, *claim*, etc.) is used to introduce previous researchers and their findings; non-reporting if no such verbs are employed. Swales claims that the "dichotomous classification works fairly well except for uncertainties that can arise with a small set of verbs, particularly *find* and *be associated with*" (p. 150). Swales illustrates this ambiguity with an example: *X was found to be impaired (Sang et al. 1972)*. This can be read as reporting: *'X was found by Sang et al. (1972) to be impaired'* or *'Sang et al. (1972) found that X was impaired'*; or as non-reporting: *'X was impaired (Sang et al. 1972)* or even *'Impairment of X occurred (Sang et al. 1972)'*. However, I believe that the context would provide the clue to whether it should be construed as reporting or non-reporting.

In his earlier study, Swales (1981) found the non-reporting/reporting ratio to be 40-60. Swales ascribes the greater ratio of the reporting type to their 'considerable discriminatory power'. Moreover, there is a large number of reporting verbs (around 50) to choose from ranging from 'highly frequent such as *suggest*, *report*, and *show* to rarities like *asseverate* (p. 151).

The use of reporting verbs have implications for the writer. The writer may wish to commit himself to the truth or otherwise of the proposition (*show*, *demonstrate*, *establish*, etc.) or he may not (*suggest*, *propose*, *examine*, etc.). The claims may then be taken as substantiated or not.

2.5.5.2 Reporting and Evaluation

The reporting verbs inevitably carry some kind of evaluation with them. As Thompson and Yiyun (1991:367) (reporting Tadros 1985) state: "the citing of another author predicts (if it does not itself carry) an evaluation of that author — the writer is, as it were, under a conventional obligation to justify mentioning the author in the first place." Thompson and Yiyun (p. 367) define evaluation as "the conveying of the writer's view of the status of the information in her text." Following is a brief account of their most relevant findings.

Thompson and Yiyun divide the reporting into two categories: *Author Acts* (AA) and *Writer Acts* (WA). The verbs in the AA category are of the following three types:

1. ***Textual*:** verbs referring to processes in which verbal expression is an obligatory component; for example, *state, write, term, challenge, underline, point out, name, deny*.
2. ***Mental*:** verbs referring to mental processes (which are, of course, expressed in the author's text; for example, *believe, think, focus on, consider, prefer*.
3. ***Research*:** verbs referring primarily to the mental or physical processes that are part of research work; for example, *measure, calculate, quantify, obtain, find*.

[Thompson and Yiyun, 1991:369-70]

These types, however, are not watertight: 'There is bleeding from one category to another" as they put it (p. 370). They cite the verb *analyse* which could either refer to a mental or research process or even both. Similarly, the WA verbs are divided into two types:

> 1. ***Comparing*:** verbs which indicate the writer's placing of the author's work in a certain perspective usually by means of comparison or contrast; for example, *correspond to*, *accord with*, *anticipate*, *contrast with*.
> 2. ***Theorizing*:** verbs which indicate the use made by the writer of the author's work in her own developing argument; for example, *account for*, *explain*, *support*.
>
> *[Thompson & Yiyun, 1991:370]*

According to Thompson and Yiyun, the AA verbs ascribe the responsibility of the process to the author cited. On the other hand, the WA verbs delegate the responsibility of the process to the writer. To illustrate their point, they provide the following example (p. 370):

> Berman's main thesis, that syntax presents difficulties to the EFL reader, would seem to **contradict** one of Cooper's findings, namely that neither practised or unpractised readers were strong on syntax ... [Alderson and Urquhart 1984:157]

In this example, the verb *contradict* is being used by the writers to point out how they perceive Berman's thesis *vis-a-vis* one of Cooper's findings. Thompson and Yiyun (p. 371) provide the following examples to clarify the two WA type verbs (the first is comparing, the second theorising):

> Thus Neisser makes reference to 'anticipatory schemata' which **corresponds to** the scenarios of Sanford and Garrod. [Widdowson 1984:224]
>
> Paulston and Bruder's (1976) work **exemplifies** the second position, which anticipates greater interference from cultural knowledge. [Steffensen and Joag-Dev 1984:49-50]

Thompson and Yiyun argue that 'the choice between Author and Writer act is a central factor in evaluation ..." (p. 371).

As far as the *evaluative potential* of the reporting verbs is concerned, Thompson and Yiyun (p. 371-2) found it necessary to consider three largely separate factors: *Author's Stance* (AS), *Writer's Stance* (WS), and *Writer's Interpretation* (WI). AS refers to the 'attitude the author is reported (in author act verbs) as having towards the validity of the reported information or opinion" (p. 372). The attitude of the author can be described in three ways:

1. ***Positive***: the author is reported as presenting the information/ opinion as true/correct; e.g., *accept, emphasise, hypothesise, invoke, note, point out, posit, reason, subscribe to.*
2. ***Negative***: the author is reported as presenting the information /opinion as false/incorrect; e.g., *attack, challenge, dismiss, dispute, diverge from, object to, oppose, question, reject.*
3. ***Neutral***: the author is reported as presenting the information/ opinion as neither true nor false at that point in his work; e.g., *assess, examine, evaluate, focus on, pose, quote, tackle, undertake.*

[Thompson & Yiyun, 1991:372]

Similarly, three options are also suggested for the WS:

1. ***Factive***: the writer portrays the author as presenting true information or a correct opinion; for example, *acknowledge, bring out, demonstrate, identify, improve, notice, prove, recognise, substantiate, throw light on.*
2. ***Counter-factive***: the writer portrays the author as presenting false information or an incorrect opinion; for example, *betray (ignorance), confuse, disregard, ignore, misuse.*
3. ***Non-factive***: the writer gives no clear signal as to her attitude towards the author's information/opinion; for example, *advance, believe, claim, examine, penalise, purpose, retain, urge, utilise.*

[Thompson & Yiyun, 1991:372]

The counter-factive option is rarely used which is in accordance with "a researcher's reluctance to explicitly disagree with a fellow researcher" (Myers 1989).

The third factor in the evaluative potential of the reporting verb is the *Writer's Interpretation* which provides four main options to the writer:

[a] ***Interpretation of Author's discourse***: the writer presents an interpretation of how the reported information/opinion fits into the author's text; for example, *add, comment, continue, detail, mention, note, recast, repeat, remark, sketch.*

[b] ***Interpretation of Author's behaviour***: the writer presents an interpretation of the author's attitude or purpose in giving the reported information/opinion; for example, *admit, advocate, assert, criticise, hint, emphasise, favour, hypothesise, insist, reiterate, remind, warn.*

[c] ***Status interpretation***: the writer indicates the functional status within her own framework of the reported information/opinion; for example, *account for, bring out, confirm, conform to, overcome, establish, popularise, prove, solve.*

[d] ***Non-interpretation:*** the writer presents the report as objective; for example, adopt, apply, calculate, analyse, map, observe, provide, recount, say, see, use, write.

[Thompson and Yiyun, 1991:373]

Justifying their grouping together of these four options, despite the fact that they appear heterogeneous, Thompson and Yiyun proceed to convincingly demonstrate that this grouping "allows us to handle neatly differences in closely-related items":

> For example, *repeat* [a] merely indicates that information appear more than once in the author's text, whereas *reiterate* [b] conveys the authors purpose in repeating information (to emphasize it). Similarly, *emphasize* [b] refers to the author's intention, while *bring out* [c] indicate that the intention has been successfully realized, in that the writer signals her agreement with the emphasis given.
>
> *[Thompson and Yiyun, 1991:373]*

The choice of verbs in the first two options is restricted to textual process verbs which largely make the process unthreatening. The first, with focus on the author's text, involves only the form, the second, with focus on author's motives, involves both the form and the content to some extent. Status interpretation, with focus shifting completely to the content of the reported proposition, includes all WA verbs (excluding those from non-Factive Writer stance) and AA verbs "which express the perlocutionary effect of the act." These verbs override the notion of 'writer distance': "the writer cannot show the status of the reported proposition in her text without signalling her attitude towards its truth value" (p. 377). The last option, with emphasis on objective reporting, has a high proportion of research act verbs and is thus more face-threatening (Brown and Levinson 1987).

Evaluation can also be carried out in other forms, such as by using negation of some kind. In this respect, Thompson and Yiyun (p.374) present two examples from the same writer:

> However, the authors **did not** specifically **compare** the bilingual child's ability in one language with his/her ability in the other. [Alderson 1984:9]
>
> Ulijin (1978) presents evidence which contradicts Cowan's theory ... He **did not find** that points of linguistic contrast caused comprehension difficulties or slower reading rates. [Alderson 1984:11-12]

The evaluative potential of *did not ... compare* and *did not find* can be established from the context. In the first, the writer seems to be criticising the authors for inadequate methodology, but he is not criticising Ulijin for inadequate findings. In the first, "the writer comments explicitly on the absence of an act that might have been expected from the authors" (p. 374).

Thompson and Yiyun (p. 375) argue that whereas a Writer act commits the author to the truth and validity of what he writes, an Author act shows his detachment and cautiousness. In short, the distinction between WAs and AAs has a crucial role to play in evaluative options (p. 377), and the writer needs to be aware of this distinction.

2.5.5.3 Tense, Aspect, and Voice

The reason for treating tense, aspect and voice under one section is that there is strong correlation among the three (Shaw 1992). When he examined the Introduction sections of some Ph.D. theses, Shaw not only discovered correlation between sentence function and tense, but also between tense and voice (past going with active and perfect with passive). According to Shaw (p. 302), "This can be explained in terms of thematization: selection of a particular noun as subject/ theme entails selection of active or passive, and with them apparently past or perfect." Tarone *et al.* (1981), in their study of two astrophysics journal articles, have correlated the use of personal pronouns with tense and voice choice. They were able to make five generalisations:

1. The use of *we* with active voice indicates a unique procedural choice while the passive indicates an established or standard procedure (I).
2. *We* with active is used for own research in contrast with other research, and the passive for the work being contrasted (IIA).
3. When contemporary work did not contrast with their own, they generally used active voice for them (IIB).
4. When referring to their own proposed future work, they used the passive (III).
5. The use of the active or the passive is determined by focus due to the length of an element or the need for emphasis (IV).

[Tarone et al., *1981:123, 135]*

Though it is generally accepted that the register of scientific English is marked by a greater use of the passive voice, results from Tarone *et al.* (1981) and Wingard

(1981) indicate that it is not always so. However, from a pedagogical point of view, we should be concerned with why such a choice is made rather than their frequency counts.

According to Swales (1990:151), "the incorporation of a reporting verb concomitantly involves a choice of tense, the selection of which may be highly indicative." Many an attempt has been made to provide an account of tense and aspect usage (Lackstrom *et al.*, 1972; Swales, 1981; Oster, 1981; Ard, 1982 & 1985; Een, 1982; Trimble & Trimble, 1982; Malcolm, 1987). The use of the Past, the Present Perfect, and the Present Simple "together realize over 90% of all finite verb usages in citational statements" (Swales, 1990:151). Swales (1990) identifies three broad approaches to the tense usage: (a) the 'general' rules are largely adequate for the purpose (Ard, 1982 & 1985; Malcolm, 1987); (b) special set of explanation of tense/aspect (closely associated with the nature of claims being made) is required (Oster, 1981); and (c) tense/aspect usage depends on the way reference to the previous researcher is introduced (Swales 1981; Een, 1982).

With respect to the first, Swales (1990) argues that the 'general' rules seem to be less operative in expository text than in narrative ones. The concept of *present-ness* or *relevance* does not apply here. Lackstrom *et al.* (1972) perceive the continuum from Past through Present Perfect to Present Simple in terms of increasing *generality*.

The concepts of *generality* and *relevance* have given rise to the second approach. Oster's (1981) hypotheses for this system are as follows:

1. The Present Perfect tense is used to claim *generality* about past literature. The past tense is used to claim *non-generality about past literature*.
2. The Past tense is used when it refers to quantitative results of past literature that are *non-supportive* of some aspects of the work described in the technical article. The Present tense is used when it refers to quantitative results of past literature that are *supportive* or *non-relevant*.
3. The Present Perfect tense is used to indicate the *continued discussion* of some of the information in the sentences in which the Present Perfect tense occurs.

[Oster, 1981:77; as quoted by Swales, 1990:152]

Commenting on these hypotheses, Swales (p. 152) claims that he did not find the third hypothesis to be directly sustainable. He did find, as he reports, instances of a corollary to this hypothesis: "the Past tense following a Present Perfect (or a series of Present Perfects) in a discussion of a particular piece of research is apparently used to indicate that discussion is terminating" (p. 152).

Based on his classification of *integral* and *non-integral* citation types, Swales (1990:153) provides a model which correlates citation types with reporting and non-reporting processes (see Figure 4).

	Integral	**Non-integral**
reporting	*Past* Brie (1988) showed that ...	*Present Perfect* It has been shown that ...(Brie, 1988)
non-reporting		*Present (or modal)* The moon may be made of cheese (Brie, 1988)

Figure 4: Reference and Tense (Swales, 1990:153)

As Swales intended to offer "a serviceable 'rule of thumb' to non-native writers" (p. 153), this model does not account for examples such as *Brie (1988) has shown that ...* or even *Brie (1988) shows that ...*

Based on the premise that both 'general' rules and 'special' ones are required to account for all the possibilities of tense usage, Malcolm (1987) has put forward the following three hypotheses:

1. Generalizations (as indicated by verbs without researcher agents) will tend to be in the Present tense. [Found to be 74% true in her sample.]
2. References to specific experiments (as indicated by a researcher agent and a footnote to a single study) will tend to be in the Past tense. [Found to be 61% true in her sample.]
3. References to areas of inquiry (as indicated by agent and/or footnote to more than one study) will tend to be in the Present Perfect tense. [Found to be 74% true in her sample.]

[As reported by Swales, 1990:153-4]

Heslot (1982:100) has attempted to characterise the choice of tense in scientific English. She arrived at the following conclusions: "(a) largely received knowledge [is] referred to with *tenseless simple present*, (b) recent works which have contributed to current view on a subject [are] referred to with *present perfect*, (c) still more recent work, provisionally supposed to fit in, [is] referred to with *simple past* (same for works mentioned for criticism)."

She was also able to explain tense, voice, and pronoun choice in individual sections — Introduction, Materials & Method, Results, and Discussion — of the research article. Her distribution of these choices is as follows:

Introduction:
General knowledge agreed upon: Present tense (some present perfect).
Reference made to other recent work: Past tense, 3rd person.
Aims of research undertaken: Past tense, presence of 1st person.

Materials and Method:
Details about technical points: Past tense, passive (1st person absent)

Results:
Well-ordered experimental data: Past tense, active (1st person absent)

Discussion:
Comparison of results with others: Past tense, 1st and 3rd person.
Evaluation: Present, presence of 1st person; modalization.

[Heslot, 1982:98-99]

But the picture is still far from clear. For example, the greatest variation in the choice of tense was found to occur in the data for hypothesis 2 (Een, 1982). Swales points out that this is because "commenting on a single paper is a key location for strategic tense choice" (p. 154). Swales believes that the progression from Past tense to Present Simple may be seen as "some kind of increasing proximity" and that "tense choice may indicate something of the author's *stance* towards the cited work" (p. 154). (See section 2.5.5.2 above for a discussion of *stance*.) Salager-Meyer (1992:101) (already discussed in the previous sub-section in connection with RA abstracts) quotes Gunawardena, which in her words, provides a very good synthesis of the conclusions arrived at by her and other researchers (including Swales, 1981) in terms of tense choice:

> It is misleading to talk about time lines with regard to the selection of tenses, because there are factors other than time-sense relationships governing tense choice in scientific journal articles. Factors such as the writer's attitude towards the importance of events, the degree of generality of the research described, or the particular context in which the discourse appears may influence the choice of tense.
>
> *[Gunawardena, 1989:272]*

2.6 Textual Analysis

Although I shall be working within the systemic framework, it is worthwhile to draw upon insights offered by the ***Functional-sentence perspective*** (FSP), associated with the Prague School of linguists. Following is a review of this approach together with associated concepts, such as *thematic progression* and *communicative dynamism*.

2.6.1 Functional-Sentence Perspective

Though developed by the Prague School linguists, the basic principles of FSP can be found in Weill (1884, 1887), in his distinction between the two interactive orders in a speech act, "the syntactic march" and "the march of ideas." Weill is said to have stated (see Maynard, 1986:78) that "it was necessary to lean on something present and known in order to reach out to something less present, or unknown." In addition, Weill identifies two aspects to the use of language in speech as "the point of departure or the ground upon which the two intelligences meet" and "another part of discourse which forms the statement."

A similar distinction is provided by Mathesius (1939) who introduces the categories of ***theme*** and ***rheme***. For him, the theme is "the starting point of the utterance which is known or at least obvious in a given situation and from which the speaker proceeds" (see Danes, 1974:106; Firbas, 1964:268). Here we see a basic departure from the concept of theme as envisaged in the Systemic-Functional approach (see below). The theme is not regarded as necessarily realised by sentence initial elements, but "how the information expressed in that sentence [given or new] relates to the information already available in the linguistic and non-verbal contexts" (Fries, 1981). While Halliday separates the ***information structure*** from the ***thematic structure***, the FSP approach combines the two. Fries (1981) terms the former as the 'separating' approach and the latter as the 'combining' approach.

It is exactly what Mathesius has been criticised for. Travnicek (1962, as cited by Firbas, 1964:208) criticises Mathesius for narrowing down the concept of theme to only conveying known information. He himself defines theme as "the sentence element that links up directly with the object of thought, precedes from it and opens the sentence thereby." While the first two points can be dismissed as 'idiosyncratic' and 'impractical' (Kurzon, 1988:157), the third point coincides with the Hallidayan concept of theme as the initial element.

In order to broaden and generalise the concept of theme, Firbas (1964) introduces a whole new concept of ***Communicative Dynamism*** (CD). Communicative Dynamism refers to the relative contribution of sentential elements to the development, the pushing forward of communication. In terms of CD, the known information, which is the theme in FSP, carries the lowest degree of CD within the sentence whereas the new information, the rheme in FSP, carries the highest CD. Firbas also introduces a third function, that of ***transition***, which carries an intermediate degree of CD. Firbas proposes a 'question-test method' for the identification of theme and rheme. If a question could be asked of a sentence, the part of the sentence that carries the answer to that question will be the rheme and the rest will constitute the theme. But the question-text method has its limitations.

It should have already been clear that the notion of thematisation is very sentence bound. Danes (1964, 1970, 1974), in an attempt to take the concept of thematisation beyond the confines of the sentence, introduces a whole new theory, the theory of ***Thematic Progression*** (TP). This theory deserves a separate section.

2.6.1.1 Thematic Progression (TP)

In response to the need for extending the scope of thematisation to encompass longer stretches of text, Danes (1964, 1970, 1974) introduced the theory of thematic progression (TP). What TP purports to fulfil is to describe discourse function of the theme. On this account, TP may be termed as ***Functional Discourse Perspective*** (FDP). TP is concerned with "choice and ordering of utterance themes, their mutual concatenation and hierarchy, as well as their relationship to the hyperthemes of the superior text units (such as paragraph, chapter ...), to the whole of text, and to the situation" (Danes, 1974:114).

TP is based on the two-point thematisation concept of theme and rheme. Basic to TP is Firbas definition of rheme as the element that "pushes the communication forward" (1964:240). Danes (1974) identifies four patterns of TP which are given below. Danes accepts other possibilities as well, but argues that they are all combinations of the three TP patterns. These patterns are based on the principle that given information ought to precede new information within sentences.

1. **Simple linear TP (linear thematisation of rheme):** the rheme of one utterance becomes the theme of the next utterance.
2. **Continuous (constant) TP:** The theme remains the same for a number of utterances with the rheme changing.
3. **TP with a derived theme:** Themes are derived from a common denominator, a hypertheme.
4. **TP with split-rheme:** Elements comprising a compound/complex rheme become themes of the following utterances one by one.

Dubois (1987:95) proposes two further TP patterns which she terms *separation* and *integration* of themes. We may be better off to refer to the first as ***split theme***. While in the *split*-theme TP, the elements comprising a compound or complex theme become themes of the following utterances one by one, in *integrative*-theme TP, the theme of an utterance embodies the themes of the preceding two or more utterances.

Danes' TP patterns have been used for both theoretical and practical purposes. Some have attempted to account for the structure of information in discourse (e.g., Dubois, 1987; Giora, 1983; Weissberg, 1984), others have attended to the pedagogical implications of the theory (e.g., Vande Kopple, 1983; Witte, 1983). The following section is devoted to a discussion of the former attempts, starting with Dubois (1987) who has provided a reformulation of the theory of TP.

2.6.1.2 TP and Discourse analysis

A major reformulation of the TP theory has been proposed by Dubois (1987). She proposes that Danes' three main TP patterns may be extended and reformulated into two main types, recoverable or given:

(a) ***themic***: from a previous theme or themes
(b) ***rhemic***: from a previous rheme or rhemes

Each may be either ***simple*** or ***multiple***, depending on whether they proceed from a single or a multiple source. Again, the former may be either ***contiguous*** or ***gapped*** 'so that repetition of theme at any degree of givenness can be called ***constant themic***. Similarly, the latter may at least be either ***(re)integrative*** or ***separative***. Dubois thus seems to avoid the terminological prefix, ***hyper***, but she admits that ***hyperthemic*** and ***hyperrhemic*** are possible subtypes. She also admits other possibilities.

Dubois started out working within the FSP framework, but ended up treating theme only as "a point of departure of the clause as message" (in Hallidayan system), and underplaying the FSP criterion of givenness and recoverability of information, the criterion which informs Danes theory of thematic progression.

Giora's (1983) study is important in that it demonstrates that the theory of TP can apply at all levels of texts. However, she limits the scope of her study by taking up only one of the TP patterns, namely, the simple linear, and by examining a selection of poems. Giora seems to be unaware of the fact that poems are organised in a totally different way. Giora also commits a terminological blunder: poetic segments are called stanzas, not paragraphs.

Of direct, *albeit* limited, relevance to the present study is the study by Weissberg (1984). Of direct relevance because it deals with the genre of the RA. And of limited relevance because it examines only paragraphs and not complete sections. A genre should be studied either in its entirety, or in terms of the standard sections. Weissberg, nonetheless, discovered that the linear pattern was the most common, more frequent in the introduction and discussion paragraphs than in the method and results paragraphs. In general, "topic development patterns based on the given/new contract" were used throughout. Despite limitations, Weissberg's study is important in that it was the first ever attempt to apply Danes' TP patterns to the RA.

The FSP approach has a number of inconsistencies. First, all of Danes' examples for illustrating TP patterns have the theme in the initial position, thus casting doubt on the

FSP proponents' claim that the theme is not necessarily sentence initial. Second, Danes (1974:121) recognises the fact that languages have special means for the purposes of TP (expressions such as ***both ... and; on the one hand .. on the other hand; in the first instance ... in the second instance***, etc.), and that

> Every text (mainly in scientific or technical prose) is interwoven with expressions signalling significant points of TP of the text. The distribution of such expressions in a particular text might be termed its network of orientation.
>
> *[Danes, 1974:122]*

But he fails to recognise that 'significant points of TP in the text' are organisational points whose signalling is the function of the theme. On the basis of his own assertion that "it is the theme that plays an important constructional role" (p. 113), all such expressions are thematic. But in the FSP tradition, they are not readily regarded as constituting the theme. Even when the FSP practitioners do recognise such expressions as thematic, they do it hesitatingly, as it requires them not only to relax the criterion of given information but that of CD as well. In fact, the development of the theories of CD and TP may be construed as attempts to get rid of all such inconsistencies. Taglicht (1984) rightly contends that:

> The Prague discussions of 'functional sentence perspective', though abounding in important insights, had been based on a heterogeneous mixture of analytical criteria, including data not only from syntax but also from intonation and from the contextual interpretation of utterances.
>
> *[Taglicht, 1984:13]*

In the systemic grammar, on the other hand, the 'theme' belongs in the textual structure, while 'given' resides in the information structure. The two are always kept apart as concepts, though, in practice, the two may sometimes merge just as the theme, as we know, is often mapped onto the 'subject', an element in the syntactic structure. "But although they are related, [they] are not the same thing. The Theme is what I, the speaker, choose to take as my point of departure. The Given is what you, the listener, already know about or have accessible to you" (Halliday, 1985:278). Let us turn now to a discussion of Halliday's systemic grammar.

2.6.2 Systemic Text analysis

Basic to systemic grammar is the notion of system networks of options or choices that exist in the lexicogrammar of a language (see Kress, 1976 for a description of Halliday's system networks). Hence, it is paradigmatic. Every major grammatical pattern is presented as a network, and interpreted as a configuration of social and linguistic functions. On this account, systemic grammar is also functional (Halliday, 1985:xiii). Further, systemic grammar is based on the assumption that human beings use language for two higher-level or metafunctions: ideational (to observe/interpret situations/environment); interpersonal (to intrude/act in social situations). These two are actualised through a third metafunction, the textual function, which refers to the user's manipulation of the resources of the language to form a text (Halliday, 1985:xiii; 1978:112-113; Couture, 1985:73-4). These three functions together make up ***register***: the classification of texts according to field (subject-matter), tenor (type of relationship between the addresser and the addressee), and mode (medium: spoken or written) of discourse. These three discourse components activate the three language metafunctions: the field of discourse activates the ideational function largely through the transitivity networks, the tenor of discourse activates the interpersonal function through the systems of mood and modality, and the mode of discourse activates the textual function through the system of theme and rheme. Consequently, variation in this configuration produce different registers. According to Halliday (1978):

> A text is a product of all three [ideational, interpersonal, textual]; it is a polyphonic composition in which different semantic melodies are interwoven, to be realized as integrated lexicogrammatical structures. Each functional component contributes a band of structure to the whole.
>
> *[Halliday, 1978:112]*

It may be because every text represents choices from the system networks of options — "A text is 'what is meant', selected from a total set of options that constitute what can be meant" (Halliday, 1978:109) — that Halliday (1978) does not impose a 'hierarchy' on the three functions. He believes that the purpose of a given investigation itself will determine a hierarchy: a psycholinguistic study will give priority to the ideational component whereas a sociolinguistic one will concentrate on the interpersonal component (p. 49). Similarly, we can say that a purely linguistic investigation will concentrate on the textual function.

A text is, therefore, both a realisation and an instance: "the realisation of meanings which are instances of the meaning potential" (Halliday, 1978:70). As such, texts are amenable to analyses of various kinds. This multivariateness gives the systemic-functional approach the "ability to characterize texts in multiple ways even *within* various semantic components" (Smith, Jr. 1986:110).

It is possible to look at the three components — along with the two ideational sub-functions: the experiential and the logical — from three different vantage points. Halliday (1978:131) provides the following classification (see Figure 5 below).

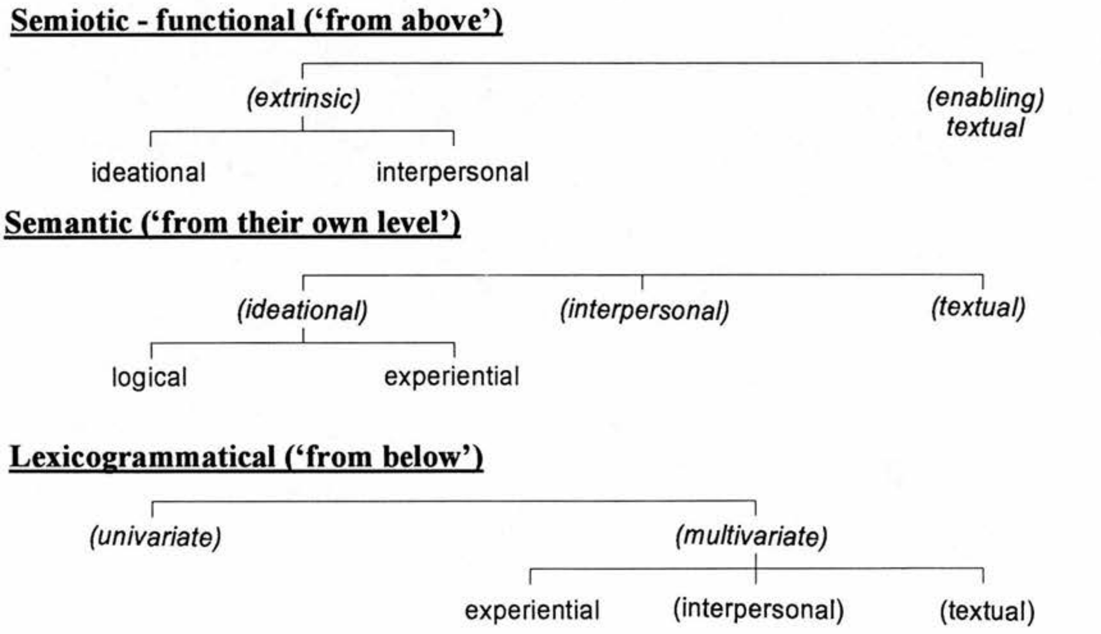

Figure 5: Functional components of semantic system, seen from different vantage points (Halliday, 1978:131).

As can be seen, every vantage point has at least one distinct component. In the lexicogrammatical system, the logical component stands out as distinct, for it is realised through recursive structures; in the semiotic system, the textual component is distinct as it performs an enabling function; and in the semantic system, the experiential and the logical go together because of greater interdependency (see Halliday, 1978:130-131).

The text-forming resources of the textual function not only depend on the mode of the text, but also extend to the semiotic (rhetorical) functions that the text may be serving: 'expository, didactic, persuasive, descriptive and the like' (*op cit.*:144-45). As such,

> The selection of options in the textual systems ... tend to be determined by the symbolic forms taken by the interaction, in particular *the place that is assigned to the text in the total situation.*
>
> *[Halliday, 1978:144; emphasis added]*

As the textual component "embodies the specifically text-forming resources of the linguistic system", it is the textual component that gives a text its texture — not alone, but in association with 'generic' structure, "the form that a text has as a property of its genre" (Halliday, 1978:133). In its enabling function, the textual component "enables the speaker to organize what he is saying in such a way that it makes sense in the context and fulfils its function as a message" (Halliday, 1973:66). We can, therefore, view text in its function as ***message***. But as message has a sender and a receiver, we can also view text in its function as ***exchange***.

In dealing with scientific texts, the linguist does not have the subject specific knowledge to understand the development of the ideational content. And in contrastive studies, such as the present one, he is in no position to compare the logical development of the argument in the texts across the samples he is analysing, particularly if the texts come from different disciplines. However, by looking at a text in its function as message and as exchange, one can get a fairly good idea of what choices the writers made from the available options and how they patterned those choices.

2.6.2.1 Text as Message (Theme & Rheme)

The textual function is represented by a set of systems that have been referred to as ***theme***: "The theme is what is being talked about, the point of departure for the clause as message" (Halliday, 1967). It is generally understood to be the initial element in a clause (Halliday, 1967:212). Also "it is that with which the clause is concerned. The remainder of the message, the part in which the Theme is developed, is called ... the Rheme." (Halliday, 1985:38).

Halliday (1985:39) regards theme as a functional category. Within the functional configuration of the clause, the theme and the rheme together organise the clause as a message with the theme providing the starting point. Although Halliday regards the theme as the initial element in the clause, he hastens to add that "First position in the clause is not what defines the Theme; it is the means whereby the function of Theme is ***realized***, in the grammar of English" (p. 39). The last phrase, 'in the grammar of English', implies that it may not be true of other languages.

Halliday makes a distinction between ***information structure*** and ***thematic structure***. Whereas Information structure concerns the distribution of information into units, usually ***given*** and ***new***, thematic structure originates in the clause and assigns the clause "a structure in terms of the functions." Thus, according to Halliday, Theme-Rheme and Given-New are two different concepts.

The theme is usually the subject, and hence occupies the initial position in a clause. However, the subject may not always occur in the initial position; it may be preceded by adverbial groups, prepositional adjuncts, and complements, etc. They are still regarded themes in the Systemic-Functional approach, but as they do not overlap the subject of a sentence, they are referred to as ***marked themes***. They are marked because the writer (or speaker) makes a deliberate choice in placing them prior to the subject. This is what Halliday refers to as ***thematic choice***. But not all such choices are deliberate, as some elements such as, certain connectors, modal adjuncts and relative pronouns, must occur initially. Such elements are inherently thematic. A distinction is also made between elements that are strongly or weakly thematic.

Strong thematic elements are those which do not have a fixed position in the clause, but the writer puts them in the initial position to achieve some special purpose or effect. And weakly thematic elements are those elements which can only occur in the initial position.

Since a clause with initial ***but*** cannot be ***about*** the word, 'but', Halliday solves the problem by saying that these inherently thematic elements do not exhaust the thematic potential of the clause; that is, a clause, in addition to such elements, can have other themes. A clause may thus have multiple themes (Halliday, 1985:53) in accordance with Halliday's tripartite division of the functions of language, ideational, interpersonal, and textual:

> Within this, the theme is what the speaker selects as his point of departure, the means of development of the clause. But in the total make-up of the clause, components from all three functions may contribute.
>
> *[Halliday, 1985:53]*

Of these, only the ideational element, the ***topical*** theme, is obligatory, the other two may or may not be present. However, as Brandt (1986:98) puts it, 'When themes do not correspond with the grammatical subject, they may provide a reader with an interpretive framework for the rest of the sentence." As such, the choice of a particular theme is significant from the point of view of text progression. Halliday (1985:62), therefore, maintains that the choice of theme is not a haphazard affair. It cannot be as it represents the 'method of development' of the text.

Despite the fact that the proponents of the Systemic-Functional approach agree on assigning the initial position to the theme, there has been some considerable debate over the scope and role of thematic position (Eiler, 1986; Lowe, 1987; Huddleston, 1988; F. Davies, 1988). Generally, there are two points of contention, two main questions that need to be answered:

> 1. What still seems to be unclear, however, is what 'point of departure' and 'aboutness' really mean when the fronted element is other than a subject or object NP; thus for instance, in what sense is a fronted temporal or fronted gerundial or fronted past participial clause or an initial if-clause a point of departure?

2. There is also the question of the domain of the point of departure. Is an initial element the point of departure for a clause and for that clause only? Or can it function as a point of departure for a stretch of discourse larger than the clause and if so how far?

[Lowe, Ivan 1987:6]

Lowe sets out to answer the questions and comes up with the following suggestions. The function of the point of departure element is to either:

(i) set the spatial, temporal, situational or individual framework within which the ensuing discourse holds (experiential component);

or (ii) give the direction in which the next part of the argument is going to go (logical component) such as with conjunction;

or (iii) give interpersonal information on the ensuing discourse, such as indicating its illocutionary force (i.e., whether statement, question, command, etc.), or setting the mood (with manner adverbials) or giving an evaluation of the importance or reliability of the information in the ensuing discourse;

or (iv) some combination of the above.

[Lowe, 1987:7]

Lowe introduces the idea of span for the point of departure. According to Lowe, the idea of span assumes a unit larger than the sentence for which the point of departure serves as a framework. When a span is initiated by a framework, it will continue until a new span is introduced by a new framework. Lowe suggests that points of departure serve to set up two different types of frameworks: individual frameworks which are often topic-like, and spatial, temporal or situational frameworks which set the ensuing discourse in space, time or situation "either by bringing in something completely new or by picking out something from the preceding linguistic context" (p. 8). Lowe also points out that

Within a span whose point of departure has already been set by a suitable temporal, locational, circumstantial or mood element in the initial position of the first sentence, most succeeding sentences will begin with subject first, a few will begin with comitatives and casuals. However, time elements and circumstantials will not be sentence initials since if they were, they would define a new span.

[Lowe, 1987:10]

According to Halliday's (1985) "The theme of any clause ... extends up to (and includes) the ideational element" (p. 56). As such, any interpersonal or textual element preceding the ideational element is part of the theme. But the theme as a unit must have an ideational element (which is often mapped onto the subject) as the obligatory element. According to Davies (1988):

> In the present formulation it is argued that Subject is not merely unmarked as Theme, but is an ***obligatory element*** in theme ... Non-subject thematic elements, by contrast, are seen to serve the distinct function of providing ***different frameworks or contexts for the development of topic*** as the discourse proceeds [original emphasis]..
>
> *[Davies, 1988:177]*

Whereas the topical elements are the ***recurrent elements***, the framing elements are typically ***non-recurrent***. The purpose of such framing elements, according to Davies, is to "signal changes/shifts or steps and stages in the progression of the discourse" (p. 178).

Initial interpersonal and textual themes are actually framing elements that provide 'circumstantial and logical frameworks of time, space, reason, manner, and purpose, etc.' Davies believes that theme choice, that of discourse frames, is very important from the point of view of the structuring of coherent discourse, for it also exerts "a powerfully constraining force on the selection of lexis, tense and voice which are permitted in Rheme" (Davies, 1988:179).

For thematic unity, the message and the purpose must be congruent with the rhetorical form of the text (Couture, 1985:79). This assertion is not new. More than two millennia ago, Longinus (?200 AD) spoke about the sublime form and the sublime idea as two ingredients of the sublime art. The form and the idea must be congruent, for if they are not, the result will be parody. In English literature, Milton's *Paradise Lost* is a classic example of such congruence: divine/grand subject expressed in heroic/epic form, whereas Pope's *The Rape of the Lock*, a parody, is now a classic example (paradoxically, Pope meant to ridicule the classicists) of non-congruence of subject and form: mundane/trivial subject expressed in heroic/epic form.

2.6.2.2 Text as Exchange

The interpersonal component is concerned with the role relationships of the addresser and the addressee in an exchange, a communicative event or situation. The interpersonal function includes "all that may be understood by the expression of our own personalities and personal feelings on the one hand, and forms of interaction and social interplay with other participants in the communication situation on the other hand" (Halliday, 1973:66). The interpersonal function depends on the roles that participants taking part in an interactive event take on. In this connection, Halliday (1978) speaks of first- and second-order social roles. Put simply, social roles of the first-order are the established roles that an individual has by virtue of his status in a communication event (employer/employee; teacher/student, etc.), "without reference to language, though they may be (and typically are) realized through language as one form of role-projecting behaviour" (*op cit.*:144). Second-order social roles come into being when individuals interact and use language for questioning, informing, responding, doubting, contradicting and the like (*ibid*). Second-order roles are in addition to the first-order roles of the participants in a communication event.

It follows that when participants interact in a communication event, they assume second-order roles in accord with their own and with respect to other participants' first-order roles. With changing first-order roles (when moving from one communicative situation to another), their second-order roles also change. By intruding into the context of situation, the addresser expresses his attitudes and judgements (Halliday, 1978:112) with respect to the addressee as well as the content of the message through the options offered in "the systems of mood, modality, person, key, intensity, evaluation and comment and the like" (Halliday, 1978:144). But the addresser will make choices from these networks in accordance with his first-order role at the moment of speaking.

The 'Mood' element relates to the addresser's assignment of speech roles to himself and the addressee (Halliday, 1978:46). According to Halliday (1985:76), "in the exchange of information, ... it is the Mood element that embodies the proposition." The mood may be indicative (declarative, interrogative), imperative, or subjunctive. As such, "the Mood element has a clearly defined semantic function: it carries the burden of the clause as an interactive event" (p. 77).

The mood block consists of two constituents: the ***subject*** and the ***finite*** (the rest is termed the ***residue***). Halliday (1985:76) defines *subject* as the element 'by reference to which the proposition can be affirmed or denied." The success or failure of the proposition is vested in the subject which may be said to be "responsible for the functioning of the clause as an interactive event." The *finite* Halliday (*op cit*.:75) defines as that element in the clause whose function it is to make the proposition definite by circumscribing it so that it becomes something that can be argued about. This function the *finite* achieves through what Halliday (*ibid*) refers to as ***finite verbal operators*** which he divides into two kinds: ***temporal*** (*primary tense*) and ***modal*** (*modality*). As tense is not touched upon in this study, let us concentrate on ***modality***.

Halliday (1985:86) makes a distinction between ***propositions*** ('information', i.e. statements and questions) and ***proposals*** ('goods-&-offers', i.e. offers and commands). Corresponding to this distinction, Halliday (*ibid*) proposes the distinction between ***modalisation*** (probability and usuality) and ***modulation*** (obligation and inclination). While modalisation, being external to the content, is clearly within the interpersonal component, modulation is part of the content of the clause, for it characterises the relation of the participant to the process, his ability to carry it out (Halliday, 1970; also in Kress, 1976:211). According to Halliday (*op cit*.:211), although "modulations are incorporated into the thesis as ideational material, they represent that part of it that is oriented towards the interpersonal — it is the content as interpreted by or filtered through the speaker that is being expressed." Modality is also represented by ***metaphorical*** forms (*op cit*.:332-340) which may have either a subjective or an objective ***orientation***. The two orientations can in turn be either explicit or implicit (*ibid*). See Chapter 7 for further discussion and examples.

In addition to finite modal operators, there are ***modal adjuncts*** that add interpersonal meanings to the clause either by qualifying the mood element itself or by adding an expression of attitude to the clause as a whole. According to Halliday (1985:82), modal adjuncts fall into two main groups: 1) Mood Adjuncts, 2) Comment Adjuncts.

2.6.2.2.1. Mood Adjuncts

Mood adjuncts can be classified on the basis of probability/obligation, usuality, inclination, time and intensity. They occur next to the finite:

a) **Probability/obligation:** probably, certainly, perhaps, obviously, definitely, positively
b) **Usuality:** usually, always, seldom, often
c) **Presumption:** evidently, apparently, presumably
d) **Inclination:** gladly, willingly, readily
f) **Time:** yet, still, already
f) **Degree:** quite, almost, totally, entirely, hardly
g) **Intensity:** just, simply, actually

[see Halliday, 1985:82]

While (a-c) are typically thematic, the rest are usually not thematic. Mood adjuncts typically qualify the mood element in the clause.

2.6.2.2.2 Comment Adjuncts

Unlike the mood adjuncts, the comment adjuncts assess the clause as a whole. These adjuncts, mostly adverbs, typically occur in clause initial position, or directly after the subject. Comment adjuncts are not part of the proposition; as such, they fall outside the mood-residue structure. Halliday (1985:50) identifies the following seven comment meanings:

a) **Admissive:** frankly, to be honest, to tell you the truth
b) **Assurance:** honestly, really, without any doubt
c) **Desirability:** unfortunately, luckily, hopefully
d) **Tentativeness:** tentatively, looking back on it, initially
e) **Validity:** broadly speaking, objectively, in general terms
f) **Evaluation:** understandably, foolishly, by mistake
g) **Expectation:** as expected, to my surprise, amazingly

[see Halliday, 1985:50]

Although *conjunctive adjuncts* do not appear to be interpersonal in the real sense of the word, they, nonetheless, achieve what may be called signalling to the reader how a particular proposition is to be taken with reference to other propositions. As such, their function is textual. Some of these are known as *metalinguistic comments*.

2.6.2.2.3. Metalinguistic Comments

Also known as metatext and metadiscourse, metalinguistic comments are defined as "the linguistic material ... that does not add anything [new] to the propositional content but that is intended to help the listener or reader organize, interpret, and evaluate the information given" (Crismore, Markkanen and Steffensen, 1993:40). Metalinguistic comments also serve to remind the reader of something that has already been discussed, to apprise him of something to come or what to expect. The writer has a number of metalinguistic devices at his disposal to achieve this purpose. Most of the conjunctive adjuncts that Halliday (1985:50, 302-309) lists are metalinguistic with the exception of temporal conjuncts which may or may not be metalinguistic. According to Martin (1983:2), temporal connectives may express "either a relation between events in the real world or a relation between rhetorical acts within a text." Similarly, Halliday (1985:305) refers to an *internal* and an *external* interpretation of the temporal connectives. The concepts of 'internal-to-text' and 'external-to-text' are difficult to isolate from one another because "distinguishing internal from external ... relations remains a problem, probably because these relations encode the speaker's interpretation of the real world more so than his perceptions of relations in the world" (Martin, p. 37).

Metalinguistic comments that draw attention to the structure of the text function at both the global and the local level: at the local level, to signal relationship between the propositions, and at the global level, to point out the relationships that obtain between the proposition(s) under discussion and the overall underlying theme. Halliday (1973:66) defines the textual function as "an enabling function, that of creating a text" and enabling "the [writer] to organize what he is [writing] in such a way that it makes sense in the context and fulfils its function as a message." If explicit indications are provided to the reader with respect to the organisation of the propositions (the ideational component), the writer is said to be making metalinguistic comments. Nash (1990:18) distinguishes between two types of writing, the one that ***tells*** and the other that ***argues*** : "***Telling*** asks nothing more of the audience than to accept what has been told; ***arguing*** in some way involves the listener or reader by appealing for judgement, inviting consent, or attempting to stave off anticipated objections." It is in the 'arguing' type (such as academic discourse) that metalinguistic comments usually have an established function.

Vande Kopple (1985), Crismore & Farnsworth (1990) and Crismore et al., (1993) have proposed a classification of metadiscourse or metalinguistic comments (see Fig. 6 below). However, strange enough, they also include modal adjuncts in this category which they refer to as *interpersonal metadiscourse*. This appears to be a misnomer. Enkvist (1975), however, restricts the use of the term to refer to the organising role of such textual elements.

I. Textual Metadiscourse (used for logical and ethical appeals)

1. Textual Markers

- Logical connectives [*and, but, therefore, in addition*]
- Sequencers [*first, second, last*]
- Reminders [*as noted earlier*]
- Topicalizers [*well, now, In regard to*]

2. Interpretive Markers

- Code Glosses [*namely, for example, what we mean is*]
- Illocution Markers [*We argue, My question is*]
- Announcements [*will be discussed later*]

II. Interpersonal Metadiscourse (used for emotional and ethical appeals)

3. Hedges (epistemic certainty markers)
4. Certainty Markers (epistemic emphatics)
5. Attributers [*According to*]
6. Attitude Markers [*I hope, unfortunately, most importantly*]
7. Commentary [*Let us,* inclusive *we*]

Figure 6: A Revised Classification System for Metadiscourse Categories (Crismore, Markkanen, & Steffensen, 1993:47).

Crismore et al., (1993) accept that there may be inconsistencies in their classification because, according to them, metadiscourse is a messy area:

> Metadiscourse is an admittedly messy but very important part of language use; thus, in studying it, we should expect a certain degree of impreciseness and subjectivity, - reconsiderations and refinements of what does or does not count as an instance of metadiscourse ... as well as classifications of metadiscourse.
>
> *[Crismore et al., 1993:54]*

It is indeed doubtful whether all of Vande Kopple's (1985), or Crismore's and colleagues' (1990, 1993) categories can be regarded as metalinguistic in every context. In order to achieve a certain degree of objectivity, it is, therefore, imperative that only those categories be included in the analysis that are instantially metalinguistic. The categories that are most likely to be metalinguistic in most contexts are the ones included in their textual metadiscourse category. I shall, therefore be proposing, following the systemic model, a new classification in Chapter 3. Mood adjuncts, comment adjuncts, modality, and metalinguistic comments will be collectively referred to by the term, *rhetorical prosodies*.

2.7 Concluding Remarks

The purpose of this rather lengthy discussion of genre, rhetoric, text as message and text as exchange was not only to establish background and focus but also to situate the present study in the larger context of text linguistics. Earlier, in Chapter 1, the type of the present study, that is, contrastive, was also emphasised. As we shall see in the chapters to come, the genre analysis and the systemic frameworks are most suitable for contrastive text linguistics as they have the potential to examine texts at several levels, from the most abstract (*the context of culture*) to the most concrete (*lexicogrammar*). In the words of Cope and Kalantzis (1993):

> analysis of the text proceeds by looking at the structure of the whole text. Only then does it account for the progress of the whole text in terms of what happens in sentences and clauses.
> *[Cope and Kalantzis, 1993:10]*

Following this, we shall first be looking at the structure of the whole text (genre), and then at sentences and clauses to account for the progress of the whole text. But before we do this, we need to develop the theoretical frameworks for the proposed textual analyses. This is the concern of the next chapter.◆

CHAPTER 3

Research Methodology & Frameworks

3.0 Introduction

This is a data-based study of one particular genre in one particular field: the geology research article. In a data-based study of discourse, it is of utmost importance that the texts comprising the datasets be representative not only of the population but of the genre as well. The reliability and validity of the results largely depend on the procedures adopted for the analyses and their consistency with the objectives of the study. Thus, for the successful completion of a study of this nature, the following need to be considered:

1. Criteria for the selection of data sources.
2. Criteria for the selection of data.
3. Criteria for the selection of linguistic/rhetorical features.
4. An appraisal of the available Theoretical/Methodological frameworks for the analysis of organisational, linguistic and rhetorical features of the texts.
5. A consideration of the statistics involved.

There is an additional caveat of comparability in comparative and contrastive studies. Purves (1988:14) points out that the texts compared should be similar on five accounts: setting, writing task, language, occupation and educational level of the writers (see Section 2.1.6 above). The two datasets selected for the study are comparable on every account. They are comparable in that they are all published research articles written in academic and research settings in English (as L_1 or L_2) by writers who are experienced academics at university faculties and research laboratories (Earth sciences) all with postgraduate degrees. The sources selected for the RAs are also respected, mainstream journals thought to serve as filters "selecting and presenting articles which are good candidates for highly-valued status in that they provide models of good practice" (Bley-Vroman and Selinker, 1984).

As the research being proposed is *descriptive* and deals with natural database, the overall objective is to gather information in order to *describe* and *discover* possible patterns, relationships, and differences between the two datasets. In the light of the research questions above (see Chapter 1), the study will focus on certain aspects of the datasets. In the following sections, the two datasets, their selection procedures, and the theoretical frameworks adopted for the study are described in detail.

3.1 The Datasets: Selection Process

In order to carry out the proposed study, two datasets were prepared for the study consisting of 30 research articles each. The Pakistani research articles were collected from a Pakistani research journal, ***Geological Bulletin***, published once a year. It is a highly reputed mainstream journal, perhaps the best in Pakistan. It also publishes papers by researchers from outside Pakistan. Working backwards in time from Vol. 23, thirty RAs were selected for the study which covers the period between 1984-1990. The reason for selecting the Pakistani dataset from one journal is that other journals were either unavailable or had very sporadic publications. A few had not been published for years.

The NSE dataset was selected from four international refereed journals: ***The American Mineralogist***, ***The Canadian Mineralogist***, ***Mineralogical Magazine*** (UK), and ***Journal of Structural Geology*** (UK). It was planned initially to select journals on the basis of ratings accorded to them by the Pakistani geologists; however, this later turned out to be unreliable, as every geologist, quite understandably, rated the journals in accordance with his/her own field of specialisation and not on the basis of a journal's general prestige within the discipline as a whole. It was, therefore, decided to select the dataset from those journals which have published the most Pakistani RAs in the past. This later turned out to be a suitable criterion as the majority of Pakistani RAs were about mineralogy and structure. Research articles were then selected by working backwards in time from the latest available issue. A period of four years from 1990 to 1993 was, thus, covered. Great care was taken not to select RAs other than those written by native speakers of English. Complete lists of the RAs comprising the two datasets are provided in Appendix A-1 and Appendix A-2.

In order to establish the identity of the RAs in the NSE dataset (chosen on the basis of names, identifiable as English or anglicisations and affiliation to anglophone institutions), the RAs were further evaluated against Swales' (1985:94) "six categories of potential evidence" of authors' first language. The six evidence types are listed below in order of decreasing frequency with reliability rating of 1 to 3. The method of their application is also provided in square brackets:

1. **Last name** (including anglicisation, etc.). [+1 when identified as NSE, -1 when not]
2. **Institutional affiliation** (assumed to be permanent unless otherwise indicated). [+3 anglophone country; -3 other]
3. **All citations** [+1 all English; -1 some/all non-English]
4. **First name** (+2 when English; -2 when not]
5. **Self-citations** (+2 all English; -2 some/all non-English]
6. **NS/NNS status relevant acknowledgement, footnote or endnote** [+3 when research grant from anglophone organisations, such as NSF or RSF; -3 when non-anglophone, or acknowledgement for linguistic help, translation, etc.]

[Swales, 1985:94-95]

Swales arrived at a total score after adding up the plus and the minus scores. For the interpretation of the total score, Swales' five rank system was used given below:

A: +05 to +12 Native speaker of English (NSE)
B: +02 to +04 Probably NSE
C: +01 to -01 Uncertain status
D: -02 to -04 Probably non-native speaker of English (NSE)
E: -05 to -12 NNSE

Where and RA had multiple authors, average of the total of individual scores was considered to determine the NNS status of the RA (p. 95).

According to Swales (p. 98), the results he obtained from a preliminary exploration looked encouraging: he found his procedure to be 90% reliable. However, he warns that NSE with permanent abodes in non-anglophone countries may be placed in category 'C' rather than in 'A' or 'B'. This warning, however, does not concern us as we needed to select RAs clearly falling in category 'A'.

All thirty RAs in the NSE dataset received a score higher than +6 (category A), establishing beyond doubt that they were all written by native speakers of English.

The selected journals are all standard journals aimed at academics and researchers in the discipline. The readers, therefore, are assumed to possess the background knowledge or content schemata — to use a term from schema theory — of the field in order to be able to understand the research reported. The RAs in both the datasets are fairly extensive with a good deal of technical data such as maps, diagrams, figures and tables.

Another consideration was to select only those RAs, both Pakistani and NSE, which had clearly author labelled introduction and discussion sections. Every RA in the two samples had clear author labelled abstract and introduction sections. However, while in the native RA dataset, the discussion section was always labelled as such, in the Pakistani dataset, two discussion sections were labelled as Implications, and Interpretations. A very wide difference was noted in the remaining RA sections. While as many as nineteen NSE RAs had the Methods and the Results sections, only five Pakistani RAs had one or both the sections. An additional Conclusion section was found to be a regular feature of both the samples, though it was found to be less frequent in the Pakistani sample.

Conflation of two sections was found to be more a trait of the NSE RAs than the Pakistani ones. While in as many as nine NSE RAs this feature was observed (conflation of the Results and the Discussion sections as well as the Discussion and the Conclusion sections), only two Pakistani RAs had the discussion and the conclusion sections conflated (see Appendix A-3, and A-4 for details).

There were approximately 87,160 words in the native dataset, and about 80,300 words in the Pakistani dataset (167,460 words in total). Average figures for the sections are as follows:

TABLE 1: Length of Native RA sections in words: [N=30]

RA SECTION	MEAN	SD	RANGE
Abstract	161	62	201
Introduction	412	198	713
Discussion	842	379	1473

TABLE 2: Length of Pakistani RA sections in words: [N=30]

RA SECTION	MEAN	SD	RANGE
Abstract	136	51	181
Introduction	304	91	401
Discussion	659	460	1926

In the native sample, the shortest introduction was only 124 words in length (NS-06), while the longest had 837 words (NS-04). On the other hand, the shortest Pakistani introduction was 158 words long (PAK-14), while the longest had 559 words (PAK-20). Similarly, the shortest discussion in the native sample was 241 words long (NS-29), while the longest had as many as 1714 words (NS-16). Likewise, the shortest Pakistani discussion section had only 183 words (PAK-18), while the longest one was 2109 words long (PAK-10). These figures for individual RAs are presented in Appendix A-5 and A-6. In the native dataset, the average ratio of the introduction and the discussion sections to the RA as a whole was 1/6.66 and 1/3.25 respectively, while for the Pakistani sample, it was 1/8.3 and 1/3.8 respectively. This shows that the native RAs were longer in every respect. These figures include all citations.

3.2 Analytical Procedures

When all my efforts to engage the services of a second judge/rater (specialist or otherwise) for judging the reliability of my identifying moves and steps failed and when I had waited long enough (more than six months) to receive questionnaires and other material (only one out of 25 was received), I decided to rely on my own intuition and linguistic knowledge. However, in order to satisfy the criterion of reliability for all analyses, I devised my own procedure.

I performed every analysis at least three times at one month intervals. After each analysis, I kept the results and the materials away out of sight for one month. Every new analysis was done with a new copy of the material. It was not a problem to get new copies as the two datasets were already computerised and edited. It was a question only of getting a new printout. At the end of three months, I had three sets of results for each analysis. The results were then compared with each other and a final result sheet for each analysis was prepared. Comparison revealed very few discrepancies which were then resolved. However, the discrepancies were so small that even if they had not been resolved, and even if such an elaborate procedure had not been adopted, the findings would have remained the same. But the confidence that I gained from following this procedure was worth the effort and time.

For genre structure analysis, the entire text itself forms the unit, the domain of analysis. And in order to identify rhetorical moves, the whole context needs to be taken into consideration. Thus, at one particular moment during the analysis, the physical eyes of the analyst will be fixed on just one sentence, but his inward eyes will be traversing the length and breadth of the entire text, making and assessing links and connections. It is, therefore, a dynamic process which involves, almost simultaneously, the following processes:[1]

1. Demarcating propositions within the overall text, and assigning functional labels (discourse values) to each;
2. Looking for linguistic (formal), and pragmatic clues (such as *Recently*, *However*, *lack of*, *little*, *In this paper*, etc.) in order to help assign functional labels (discourse values);
3. Assessing the nature of a particular proposition (its communicative intention) in the overall context (overall communicative purpose) in relation to other propositions.

For Bhatia (1993:86), how to identify moves in a text is an operational question. He suggests that "the focus of analysis be on the functional rather than the formal characteristics of linguistic data" since "it is not always possible to find one-to-one

---

[1] Nwogu (1990:100) has proposed five procedures for analysing schematic structure of texts. My three processes seem to encompass his five procedures. (I am thankful to Jean Ure for giving me a copy of the monograph.)

correlation between [the] formal and [the] functional aspects of language use" (*ibid.*). As such, Bhatia holds that:

> although surface signals are fairly reliable indicators of discoursal values in a majority of discourse contexts, the ultimate criteria for assigning discourse values to various moves [should be] ... functional rather than formal.
>
> *[Bhatia, 1993:87]*

Given that the communicative purpose of a genre is known, the moves comprising that genre can be identified fairly reliably, since each move in a given genre "serves a typical communicative intention which is always subservient to the overall communicative purpose of the genre" (*op cit.*:30).[2]

For analysing the schematic structure of the Introduction section, I adopted a top-down procedure as I was following an already existing model, the *CARS* model for article introductions (Swales, 1990). The procedure was to look for propositions that could be assigned the labels proposed in the model, and to note where and when the introductions deviated from the model.

The procedure for analysing the discussion section was bottom-up. First, various propositions were demarcated and then, on functional/pragmatic considerations, they were assigned labels. The frequency of individual acts were then taken into account to assign the acts to different Moves that make up the model. This procedure is discussed in detail in Chapter 5.

For genre analysis, all sixty introductions and discussions were used; however, for detailed comparison of moves and for some of the later studies, it became necessary to use smaller samples. Accordingly, four samples were drawn from the two datasets: two samples each of six introductions, and two samples each of six discussions. As the aim was to have samples of comparable length, the following procedure was adopted.

---

[2] A comprehensive definition of *move* is provided in Chapter 4 in terms of text structure as *activity structure* (or genre) and activity structure having a *dynamic* and a *synoptic* meaning (Lemke, 1988).

First, those introductions and discussions which were either longer or shorter by half standard deviation (SD) from the mean length (in number of words) were selected from the two datasets. Second, six introductions and six discussions each from the two selections were drawn at random. As expected, the samples turned out to be of almost equal length with mean lengths of 404.17 (native) and 323.33 (Pakistani) for the introductions, and 667.5 (native) and 646.5 (Pakistani) for the discussions. The effect of length may, therefore, be totally disregarded. The four samples consist of the following RAs:

TABLE 3: Introduction Samples

1. **Native:** NS-01, NS-07, NS-14, NS-16, NS-25, NS-26
2. **Pakistani:** PAK-04, PAK-08, PAK-12, PAK-18, PAK-22, PAK-26

TABLE 4: Discussion Samples

3. **Native:** NS-02, NS-07, NS-11, NS-17, NS-27, NS-28
4. **Pakistani:** PAK-02, PAK-05, PAK-13, PAK-16, PAK-21, PAK-28

In drawing the sample from the Pakistani introductions, the introductions which were found to have no Move 2 (see Chapter 4) were excluded from sampling.

The two sets of samples each make 20% of the total number of introductions (60) and discussions (60) in the datasets. In number of words, the introduction and the discussion samples respectively make 20.3% and 17.46% of the total number of words in the 60 introductions and 60 discussions. These samples are referred to in the study as the NSE samples and the Pakistani samples.

3.3 Analytical/Theoretical Frameworks

According to Halliday and Martin (1993), scientific English is a variety of English which has special probabilities attached to it. As such, scientific English is

> a form of English in which certain words, and more significantly certain grammatical constructions, stand out as more highly favoured, while others correspondingly recede and become less highly favoured, than in other varieties of the language.
>
> *[Halliday and Martin, 1993:4]*

If we recognise, as we do, that there is such a thing as 'scientific language' and that it has features that make it distinct from other varieties, then "it must be possible, using the theories and methods of linguistics, to say what its special features are" (Halliday, 1993:124). To discover and explain these features, we need to look for them in the text, but:

> *where* (at what level, or levels) in the linguistic system do we explain them? Are they in the lexicogrammar — that is, in the meanings constructed into sentences by the syntax and the vocabulary? in the discourse — the composition of the text and its rhetorical structure? or in some higher order the ideological framework of knowledge, beliefs and value systems that form the cultural context of the text?
>
> *[Halliday, 1993:124]*

Halliday's (*ibid.*) answer is that "the concept of 'scientific language' involves all three." Halliday maintains that all three — lexicogrammar, text structure, and some higher order abstraction (such as ideology) — "participate in the creation of meaning ... [with] certain components ... more accessible, more under conscious direction than others" (*op cit.*:125). The experimental research article is one such text whose rhetorical organisation is "easy to observe and fairly easy to prescribe" (*ibid.*).

While the text structure establishes the ***macro-movement*** of the text, the lexicogrammar develops its ***micro-movement*** (Halliday, 1993:125). Cope and Kalantzis (1993) express a similar view when they write:

> analysis of the text proceeds by looking at the structure of the whole text. Only then does it account for the progress of the whole text in terms of what happens in sentences and clauses.
>
> *[Cope and Kalantzis, 1993:10]*

Accordingly, this study focuses on the *macro-* as well as the *micro-movement* of the geology RA and aims to compare the NSE and the Pakistani geology RAs on these two accounts.

To begin with, *genre analysis* can be divided into four distinct stages. And as such, there are four important aspects which need to be identified before a genre can be described adequately: 1) aspects of the discourse community; 2) aspects of the genre itself; 3) aspects of the register the genre employs; and 4) aspects of the language used. These aspects can be spelled out as follows (see Chapter 2 for definitions of discourse community, genre, and register):

1. ***Aspects of Discourse Community***: Being a *socio-rhetorical* concept, the primary determinants of a discourse community are largely socio-rhetorical. The functioning of a discourse community is regulated by rules and conventions: linguistic, academic or professional. The genre analyst needs to take stock of these determinants.
2. ***Aspects of Genre***: Being a *rhetorical* concept, the primary determinants of genre are largely rhetorical. One genre is distinguished from another in terms of form, function, and features (registerial and linguistic). These must be determined individually and in relation to one another.
3. ***Aspects of Register***: Register is a *socio-linguistic* concept determined by such semantic variables as *field*, *mode* and *tenor* correlated to ideational, textual and interpersonal meanings, respectively. Interpersonal includes the choice of formal vs. informal variants. A genre will have a specific combination of the three variables. The nature of all these determinants needs to be considered.
4. ***Aspects of Language***: The language plane is concerned with lexis (vocabulary), grammar and phonology which make up the discourse. Since language, as we know, is the resource for making meanings, a genre will have specific lexicogrammatical features to realise meanings in accordance with the writer's intentions.

This is a task that requires the analysis of a number of different determinants and variables; hence, the suggestion to begin the analysis with the aspects of discourse community. This will help the analyst eliminate, while working downwards, all those features for consideration which are not expected to be present in the genre being analysed.

Bhatia (1993) has also proposed a similar procedure which is given below:

1. Placing the given genre-text in a situational context
2. Surveying existing literature
3. Refining the situational/contextual analysis
4. Selecting corpus
5. Studying the institutional context
6. Levels of linguistic analysis
   Level 1: Analysis of lexico-grammatical features
   Level 2: Analysis of text-patterning or textualization
   Level 3: Structural interpretation of the text-genre
7. Specialist information in genre analysis

[Bhatia, 1993:22-36]

Bhatia's procedure is not only unnecessarily prolonged, it also lacks logical sequence. For example, whereas stages 1, 3 and 5 in his procedure comprise what I collectively call *aspects of the discourse community*, his stages 2, 4 & 6(3) are concerned with *aspects of the genre* in my procedure. Similarly, his levels 1 & 2 of linguistic analysis (Stage 6) belong respectively in my proposed procedure to *aspects of the language* and *aspects of the register*.

Bhatia (1991, 1993) also includes in his procedure a final step, that of validating one's "findings against reactions from a specialist informant, who, generally, is a practising member of the disciplinary culture in which the genre is routinely used" (1993:34). This is important and interesting — important because it will validate the findings, and interesting, in terms of my procedure, because the analyst will have turned full circle, and if he finds anything wrong with his findings he can start over again there and then.

3.3.1 Aspects of Discourse Community

As this study is concerned with a single discourse community (disciplinary culture), and no cross comparison of discourse communities is intended, this variable appears to be less important. However, it is still worthwhile to present an overview of the discourse community of the geologists.

But, first, a taxonomy of scientific disciplines. Scientific disciplines have been classified and grouped on a number of accounts. Thus, there are scientific disciplines which are either physical, natural, or social. They can be either hard or soft. They can also be biological or non-biological, and so on. In general, they all deal with classes of phenomena of one kind or another: physical, natural, or social.

Halliday and Martin (1993) refer to the complexity of such phenomena with respect to each other. According to them, the complexity of a class of phenomena increases as we move from the physical to the social:

> A physical system ... is purely physical in nature; but a biological system is both biological and physical, while a social system is at once all three.
>
> *[Halliday and Martin, 1993:16]*

Consequently, the kind of abstraction that is involved in construing these various systems become progressively more difficult to understand and report, for "a 'biological fact' is more problematic than a 'physical fact', and a 'social fact' is more problematic still" (*ibid.*).

It follows that the nature of the class of phenomena that a discipline finds itself concerned with determines the complexity of that discipline and the conventions and norms that evolve to deal with that complexity and abstraction. As a result, disciplines are either predominantly exploratory, or predominantly problem-solving.

Geology is concerned with physical objects, produced, shaped and changed by natural phenomena over millions of years. It is interesting to see that geological approximations for natural phenomena are usually in the order of millions of years (e.g., ±2 MY). Geology may be either predominantly exploratory or predominantly problem-solving depending on the aims of the researcher. While in academic settings, the research is predominantly exploratory, in other spheres, such as geological organisations, the research becomes predominantly problem-solving. Even when academic scholars undertake research for such organisations, their approach becomes problem-oriented.

However, it is also possible for an exploratory research to turn into a problem solving or hypothesis testing research. For example, a geologist may sometime happen upon an unusual occurrence (a rock type, a mineral, a feature) that does not fit into the overall geological scheme of things of the area being explored. This discovery will be treated as a problem. To begin with, the geologist will need to make a hypothesis in order to explain this unusual occurrence. His hypothesis may require him to undertake an extensive fieldwork in the same area in order to discover other such occurrences. As a result, the geologist may either propose a new theory or he may simply offer an explanation for the unusual occurrence.

Geological research, exploratory or problem-driven, depends both on fieldwork and on laboratory work. We, thus, find both tentativeness (approximation) and exactness in geological research.

3.3.2 Aspects of Genre: Genre Analysis

The genre analysis framework adopted here is that of Swales (1990). For RA introductions, I adopt the *CARS* model. The discussion section has not yet been adequately analysed to help devise a model that would adequately characterise its macrostructure. I shall therefore draw upon the model (still tentative) proposed by Hopkins and Dudley-Evans (1988).[3] Insights from other models suggested for RA discussions in specific fields such as medicine (McKinley, 1983; Adams-Smith, 1984), and psychology (Hill *et al.*, 1982) are also considered for developing a model for use in this study.

3.3.3 Systemic-Functional Framework

The major theoretical and analytical principles of systemic grammar have already been discussed in Chapter 2. This section is concerned with the application of the model to a contrastive analysis of NSE and Pakistani geology research articles.

The systemic model is based on a network of linguistic systems consisting of options of potential meanings from which speakers and writers choose to make meanings. These choices result in a specific configuration of field, mode, and tenor (*register*). The resulting text also exhibits the writer's semantic choices in the experiential, the textual and the interpersonal domains. These semantic choices are realised through the lexicogrammar of mood, transitivity, and theme.

One paramount feature of the systemic model is that it allows us to look at texts in both an inductive (predictive) and a deductive fashion. Given that the context of situation and the genre of a text are known, we can predict with reasonable accuracy the choices that the writer made, down to the level of lexicogrammar. Similarly, looking at the lexicogrammatical choices, we can deduce the context in which the text

---

[3] Dudley-Evans has now (1994; in Coulthard, M. (ed), *Advances in Written Text Analysis*) developed the model for the discussion section he initially proposed with Hopkins (Hopkins & Dudley-Evans, 1988). However, I feel that the model needs further refinement. Chapter 5, in which I propose a model for the discussion section, was already in final shape when I discovered Dudley-Evans' paper. It was too late for me to make full use of it; however, I have referred to it in footnotes wherever necessary.

took shape as well as its genre. As such, the systemic model has the potential to be most suitable in a contrastive study of the kind undertaken here. First, if two texts belong to the same genre and the same context of situation, variations in lexicogrammatical choices may be construed as having to do with the status of the writers: experienced/less-experienced/novices, etc. Second, if the statuses of the writers are also similar (in terms of experience, education, etc.), the variations may be due to linguistic or cultural background.

Moreover, the systemic model can be used to ***understand*** as well as ***evaluate*** texts. It depends on the level of achievement that one aims at. While the lower level linguistic analysis "enables one to show how, and why, the text means what it does" (Halliday, 1985:xv), the higher level linguistic analysis "may enable one to say why the text is, or is not, an effective text for its own purposes — in what respects it succeeds and in what respects it fails, or is less successful" (*ibid.*). The higher level goal is harder to achieve, for

> It assumes an interpretation not only of the environment of the text, its 'context of situation' and 'context of culture', but also of how the linguistic features of a text relate systematically to the features of its environment, including the intentions of those involved in its production.
>
> *[Halliday, 1985:xv-xvi]*

The relationship that exists among all the different levels of the model make it an effective tool for performing this higher level text analysis. And this is what this study hopes to achieve.

3.3.4 Theme Choice Framework

It has already been discussed in section 2.6.2.1 above that the thematic system as proposed by Halliday (1985) depends on the clause being divided into two main constituents: a theme and a rheme. Since it is possible for a number of clause elements to occupy the first position in a clause, we can identify different types of themes.

The systemic network of theme offers us three major types of themes: unmarked, marked, and postponed. As the choice of unmarked theme is the most typical/usual choice, the writer will make this choice most of the time unless he has good reasons

— textual, rhetorical, pragmatic — to choose the marked or the postponed theme which are the atypical choices.

In this study, following Halliday, the theme is understood to be the initial element in a clause (Halliday, 1967:212). According to Halliday:

> The theme is the element which serves as the point of departure of the message; it is that with which the clause is concerned. The remainder of the message, the part in which the Theme is developed, is called ... the Rheme.
>
> *[Halliday, 1985:38]*

As such, the theme and the rheme perform different functions within the clause: the rheme "pushes the communication forward" (Firbas, 1964), while the theme organises the text and "plays [a] ... constructional role" (Danes, 1974:113).

There are two strands to Halliday's definition of theme: a) it is the point of departure of the message, and 2) it is (or includes, always) what the clause is about. The second strand appears to have eluded even some systemists; for example, Downing (1991) believes that it is doubtful to accept that the theme is always what the clause is about, although she accepts that it is, without doubt, always a point of departure of the clause. The concept of ***multiple themes*** and Halliday's (1985) assertion that "There is always an ideational [topical] element in the Theme" (p. 53) should have solved this problem. The ***experiential theme*** is always what the clause is about, and, if it is also clause initial, it becomes the point of departure of the clause as well. The experiential theme, however, may be preceded by a theme of the ***interpersonal*** and/or the ***textual*** kind; in which case, the left-most constituent takes over from the experiential theme the function of the point of departure of the clause though the experiential theme still remains what the clause is about. In accord with this typology, while any one of the three functions — the experiential, the interpersonal, and the textual — could be the points of departure of a clause, only the experiential could be the topic of the clause, or, in other words, what the clause is about.

If the theme is mapped onto an element which is not the subject of the clause, we get what Halliday (1985:45) refers to as *marked* theme. This makes all clause initial adjuncts, conjunctions, relatives and complements instances of *marked themes*. As is obvious, they all perform different functions in the clause; they are, in fact, points of departure of different kinds.

In the following sections, each theme type is discussed in detail with instances from the two datasets. Important differences and criteria for distinction are also pointed out.

3.3.4.1 Unmarked Theme

The unmarked theme constitutes the most usual or typical choice that a writer (and speaker) can make from the theme network. This choice is dictated by the mood of the clause (Halliday, 1967:212 and 1985:44). The three mood types — declarative, interrogative (polar and non-polar), and imperative — differ in the selection of a clause-initial element as theme: subject, finite, Wh-element, and process. Thus, in declarative mood, "the Theme is [typically] conflated with Subject" (Halliday, 1985:44), and therefore represents the topic of the clause. According to Halliday (*op cit.*:213), "The subject is that nominal which, together with the finite verbal element, fulfils a modal role in the realization of speech function." The theme of the declarative clause may be a single noun group (Example 1), a complex noun group (Examples 2 & 3), or a nominalisation (Example 4):

(1) ***The polyhedron*** can adjust its configuration to adapt to the small cation by movement of the cation ... [NS-05]

(2) ***Our previous calculations (R), which employed considerably larger basis sets***, gave a shielding difference (after core correction) of 93 ... [NS-07]

(3) ***The amount of ammonium that may have been present in the magma originally*** cannot be known. [NS-01]

(4) ***The assignment of the peak at F of -193 to AlF (R)*** seems reasonable in light of the good match to M_3AlF_6. [NS-07]

In a Wh- interrogative, the Wh- element indicates that the writer (speaker) wants to know something that he does not know. As the Wh- elements (Who, What, When, How) conflate with Subjects, Complements or Circumstantial Adjuncts, the Wh-element ***is***, therefore, the point of departure for the message and "it is precisely what is being talked about" (Halliday, 1967:212).

(5) ***Why*** is etch tunnel formation sensitive to the chemical environment stabilised by the pressure assembly? Most problematic of all, *when* do etch tunnels stop growing and start healing? [NS-06]

This generalisation also holds for the polar interrogative, as Halliday (*op cit.*:213) proposes. That is, "the theme of the message is the demand for the resolution of the binary option marked by [the finite element of the verbal group]" (*ibid.*). However, in this case, the theme of the clause, in addition to the finite element, "extends over the Subject as well" (Halliday, 1985:48). No polar interrogatives with the finite element in the initial position were found in the discussion sections from the two datasets. The only example of polar interrogative had a discourse theme (see below) preceding it:

(6) For example, ***are*** impurities segregated on growth dislocations in San Carlos olivine ... ? [NS-06]

Strictly speaking, the imperatives have no implicit theme (Halliday, 1985:49). However, as the first position is strongly thematic, the predicator is accorded the status of theme (*ibid.*). Thus, the predicator constitutes topical theme in an imperative, for it plays the transitivity role of process in the clause.

(7) ***Note*** also that the Cu-Cl apical distances are generally shorter in the mixed-ligand structures than in tolbachite ... [NS-01]

Halliday (1985:49) suggests that such imperative clauses may also be analysed in another way: by interpreting them as messages of the kind 'I want you to do something'(*I want you to note that*). Similarly, if the predicator is preceded by *You*, *Let's* or *Do*, these elements constitute the unmarked theme of the clause.

3.3.4.2 Marked Theme

Now and again, the writer/speaker may opt for foregrounding his point of departure by selecting a marked theme rather than the typical unmarked theme. The writer has the choice to thematise, a prepositional phrase functioning as adjunct in the clause (Example 8), or a complement[4] (Example 9).

---

[4] For Halliday (1985:45), this is the 'most marked' type of theme in a declarative clause: for example, *this responsibility* in *This responsibility we accept wholly*. And "even the Complement from within a prepositional phrase [may function] as theme, particularly in idiomatic combinations of preposition and verb: for example, *two things* in *two things we need to comment on."*

(8) ***Of the two authigenic phases***, the low-(Ce/La) ellipsoids appear to postdate the high-(Ce/La) veinlets. [NS-13]

(9) ***Of more significance in explaining the characteristics of the group*** are the unusually short H1-F3 distances ... [NS-09]

I also include in marked theme initial dependent clauses. Referred to as clausal themes, they occur in ***the clause complex***. They are, therefore, one step above the clause (Halliday, 1985:56-59). Syntactically, the dependent or the modifying clause follows the independent (or the major) clause. "But the reverse order is also possible, with the modifying clause preceding [the independent clause]; and where that order is used, the motive is thematic" (Halliday, 1985:57). That is, the initial element may be there as an expression of theme choice (it may equally occur elsewhere in the sentence) or as an expression of grammatical restriction (it can occur in initial position only). Following are a few examples:

(10) ***When crystal symmetry restricts the motion of both cation and anion ...***, larger than normal bond distances and thermal motion may occur (R). [NS-05]

(11) ***Because potassium is the only major element for which it can easily substitute***, the only rock-forming minerals that carry ammonium are those that also can contain potassium, i.e., feldspars, micas and zeolites. [NS-11]

(12) ***As the fluid lens is driven away from the site of initial hydraulic fracturing***, bedding-plane slip ceases at this locality and the system locks up. [NS-28]

(13) ***Although the heavy mineral assemblage appears fairly similar across the molasse succession***, there is a marked change in the relative abundance of different minerals at various stratigraphic levels. [PAK-02]

(14) If the faults were less symmetric about the bedding and/or block rotation was more, then a bulk pure shear restoration might not be effective ... [NS-27]

The clauses in each of the above examples are in hypotactic relationship with the dependent clause in the initial position. However, it is perfectly possible for the dependent clause to occur in the final position. As such, the positioning of the dependent clause in the initial slot may be considered a deliberate theme choice on the part of the writers; hence, constituting marked theme.

Kies (1988) distinguishes between *unreinforced marked themes* (UMTs) and *pronominally reinforced marked themes* (PRMTs).[5] He argues that the UMTs have a

---

[5] I have a hunch that PRMTs (*pronominally marked themes*) rarely occur in written English (See Quirk et al., 1985:1310, *Postponed and anticipated identification*). Kies (1988) uses spoken interview data in his study. This should be clear from these two examples as provided by Kies: *Other perople, girls on the street, ask me for my autograph and I give it to them* (UMT) and *Other people, girls on the street, **they** ask me for my autograph and I give it to them* (PRMT).

connective function (lexical cohesion), while the PRMTs have a presentative function (pp. 52; 60-62), in addition to what Chafe (1976) terms as their general contrastive function. Kies (p. 57) also suggests that their syntactic properties indicate that they are *presupposed*, not *asserted*: "They presuppose the existence of, and succeed in identifying, the object about which something could be said" (p. 59). Further, "PRMTs *re-establish* an earlier discourse topic" while "UMTs *maintain* a discourse topic" (p. 63). Surprisingly, a slightly different type of PRMT was found in the Pakistani sample with an indefinite pronoun, *all*. In this example, the indefinite pronoun *all* refers back to the list that is provided as evidence of the phenomenon:

(15) *Fluxion structure and mortar structure superimposed on "volcanic flow" type of texture, broken and elongated grains of quartz and feldspar, broken aggregates of these large crystals, the laminated groundmass indicating abrupt variation in grain size and in some cases indications of [sic.] recrystalization and neo-mineralization,* ***all*** provide ample evidence of this phenomenon. [PAK-06]

Kies' PRMT appears to be what is known as 'left dislocation' or 'anticipated identification' in common terminology (Quirk et al., 1985:1310): i.e., "where a noun phrase is positioned initially and a reinforcing pronoun stands 'proxy' for it in the relevant position in the sentence" (*ibid.*). Halliday (1985:40) refers to this construction as 'picking up' of the theme by a pronoun later in the clause.

3.3.4.3 Multiple Theme

As already mentioned, the notion of multiple theme derives directly from the principle that a clause represents three kinds of meaning: experiential, interpersonal, and textual. Of the three, only the experiential element is obligatory as it represents an experience functioning as predicator, subject, complement or circumstantial adjunct in the mood structure of the clause; hence, also referred to as the ***topical theme***. The interpersonal and the textual elements may or may not be present. This thematic potential of the clause gives us three possible configurations:

1. Interpersonal^Topical
2. Textual^Topical
3. Textual^Interpersonal^Topical

As already discussed above, the initial elements in these three configurations constitute the point of departure of the message as a whole. As they are optional, their presence indicates the writer's deliberate choice. Although a clause may have more than one textual and/or interpersonal element, it can have only one topical element. The principle of one topical theme per clause is based on the fact that once an element is assigned a transitivity role and made the topic of the clause, the thematic potential of the clause is said to be exhausted. The following examples from the two datasets serve to illustrate these multiple themes:

(16) ***Unfortunately***, such ambiguity is difficult to eliminate completely in comparing halides and chalcogenides ligands. [NS-07]

(17) ***In addition***, Figure 2 shows that changing pressure also changes the equilibrium plagioclase composition, providing a further driving force for resorption. [NS-03]

(18) ***Interestingly***, whereas the strata older than this age are almost always cross cut by basic dykes, there is a sharp lack of basic dykes and sills in the younger (post Permian) strata (Pogue, personal communication). [PAK-12]

(19) ***However***, large bodies of hornblende-rich gabbros and diorites occur elsewhere in the world. [PAK-05]

The next type of multiple theme I call *discourse themes*.[6] They are typically ***non-recurrent***. Halliday (1985) refers to all such elements as *conjunctive adjuncts* which relate a clause to the preceding text. They fulfil three functions: 1) they, most typically, pick up a topic from the previous discourse and make it a point of departure for the ensuing message; 2) they do not name a topic as such, but cohere with a previously mentioned topic by referring to it; and 3) they establish a relationship between the previous text and the ensuing clause (see Table 3(2) in Halliday, 1985). They are the most overt of what Lemke (1988) refers to as 'rhetorical and genre structures' that help in maintaining discourse coherence:

> Thematic and structural organization in a text are complementary in the interests of maintaining its coherence (and, *a fortiori*, its cohesiveness). When thematic continuity is at a minimum, e.g. when there is total change of topic, coherence is maintained by rhetorical and genre structure, so that the new topic may be seen as a digression, a new case, or example of a specific sort which will later be synoptically reintegrated somehow into the structure of the text.
>
> *[Lemke, 1988:168]*

---

[6] These are basically conjunctive adjuncts which are also known as discourse adjuncts; hence, the name, *Discourse theme*. The difference between discourse theme (conjunctive adjuncts) and textual theme (conjunctions), according to Halliday (1994:50), is that "while conjunctive adjuncts [discourse themes] set up a semantic relationship with what precedes, conjunctions [textual themes] set up a relationship which is (not only semantic but also) grammatical ..."

And according to Davies (1988), the purpose of such discourse elements is to "signal changes/shifts or steps and stages in the progression of the discourse" (p. 178). Take, for instance, the following examples:

(20) [1] Our experimental procedure involves three assumptions in relation to the magmatic processes being modeled.... [7] ***In regard to the third assumption***, adiabatic cooling must be less than the depression of the plagioclase liquids caused by decompression. [NS-03]

(21) ***As for montmorillonite***, it occurs in four special environments: in soil profiles, in basic chemical sedimentation, in bentonites (altered volcanic ash) and in hydrothermal veins. [PAK-16]

(22) ***Taken together***, the evidence suggests the development of a Middle Palaeozoic passive margin and the opening of an ocean, possibly the Palaeotethys. [PAK-21]

In these examples, the discourse themes point back to the previous stretch of discourse as points of departure for the succeeding message. In short, conjunctive adjuncts construct a context for the clause (Halliday, 1994:84).

3.3.4.4 Postponed Theme (Theme as New)

This category consists of three types of themes: ***predicated***, realised by cleft (Halliday, 1985:59-61) and pseudo-cleft (also referred to as *thematic equative* by Halliday, 1985:43), ***anticipated***[7], realised by extraposition, and ***existential***, realised by presentative *there* and empty *it*. These themes may also be referred to as *proxy* themes, for the *it* and *there* used so act as proxy to some other element in the clause.

Cleft and pseudo-cleft constructions are the means by which a particular element of the clause is given both *thematic and focal prominence*. One major communicative difference between cleft proper and pseudo-cleft is in relation to focus. While the cleft is "often used to put the main focus near the front of the sentence, the pseudo-cleft is chiefly used to postpone the focus to end position" (Quirk et al., 1985:1389). Although cleft sentences are "less rhetorically obtrusive," they "provide unerring guidance to the reader in silently assigning appropriate prosody" (*ibid.*). And

[7] The main difference between the *predicated it* and the *anticipated it* themes is that the former acts as a proxy for an element within the same clause while the latter for an element in the *that*-clause.

according to Jones and Jones (1985:11), the most general overriding function of both cleft and pseudo-cleft sentences is to indicate thematic prominence in a discourse. Marking themes with clefts and pseudo-clefts also brings to surface the writer's subjective perspective. Chomsky (1971) refers to clefts as *focus-presupposition* constructions which structure the proposition into two parts: an open proposition ('given' information) and an instantiation of the variable in that open proposition ('new' information). Examples of *it*-clefts are given below. No *wh*-clefts were found in the two datasets.

(23) *It is the petrography* which would decide about [sic.] the dominance of the mechanism responsible for myrmekites in a particular set of rocks. [PAK-13]

(24) [...] it is because of the overall symmetry of the system and general lack of block rotation that the restoration appears to be reasonable and successful. [NS-27]

Extraposition is achieved by the use of *it* which is known as the ***anticipatory*** *it*. A sentence having *extraposition* has two subjects: the postponed subject, and the anticipatory subject. The anticipatory *it* has a pronominal correspondence to an item later in the sentence, the notional subject. The normal subject position is occupied by the anticipatory pronoun *it*, while the subject is moved to the end of the sentence (Quirk et al., 1985:18.33-18.36). Extrapositon usually marks author comments (Jones & Jones, 1985:13). Two examples are given below:

(25) *It* may well be that *the existence of the third slip plane parallel to the bedding* constituted an element of planar anisotropy ... [NS-27]

(26) *It would be interesting to generate* analogue models with a bedding plane slip component. [NS-27]

Clauses that do not have more than one participant require the use of the ***existential there*** or the empty or prop *it* which assume the subject function without acquiring any semantic content (Quirk et al., 1985:10.26). "The existential sentence has been described as 'presentative', in serving to bring something on to the discourse stage deserving our attention" (*op. cit.*:18.49). And one type of *there* existential sentence (*There + be + NP + relative clause*) resembles the cleft sentence in its rhetorical motivation. The use of *there* necessitates the postponement to a more 'focused' position an element which conveys 'New' information. For a detailed discussion of existential sentences, see Quirk et al., (1985:18.44-54). Two examples are given below:

(27) [...] *there* are published results of analyses showing more than 10 ppm ammoniacal nitrogen in some volcanic rocks (compilation of Wlotzka 1972). [NS-11]

(28) *There* are igneous as well as metamorphic hornblendes, and the chemical data are not sufficient to distinguish the origin of the amphiboles in the complex. [PAK-05]

In this thematic network, only marked, postponed, textual and interpersonal themes represent atypical choices. In the context of this study, then, theme choice refers only to the use of these types of themes. *It needs to be pointed out that postponed themes may also have modal (*e.g., it may well be*) or textual meaning (*e.g., It follows that*); hence, for the purpose of this study, they are categorised as interpsrsonal or textual themes (see Appendices D-1 & D-2).*

Although the main framework for the study of theme will be that of Halliday (1985), the framework suggested by Fries (1981) known as *method of development* will also be used. By method of development Fries means the continuity of themes in a passage. Fries, like Halliday and unlike Danes (1974) defines theme as the initial (ideational) element of the clause (1983:119). Concentrating only on theme accords well with Halliday's view that

> In the Theme-Rheme structure, it is the Theme that is the prominent element.... by analysing the thematic structure of a text clause by clause, we can gain insight into its texture and understand how the writer made clear to us the nature of his underlying concerns.
>
> *[Halliday, 1985:67]*

It is our concern to discover whether the NSE and the Pakistani writers differ in how they signal their underlying concerns through theme choice and method of development.

3.3.5 Rhetorical Prosodies Framework

The concept of *rhetorical prosodies* that I use in this study is derived from Halliday's (1985:169) assertion that "Interpersonal meanings tend to be scattered prosodically throughout the unit."[8] I include in the rhetorical prosodies some of the textual elements which either comment on the ideational content of the clause or signal text structuring: "textual meanings tend to be realized by the order in which things occur, and especially by placing of boundaries" (p. 169). In this study, the term also includes elements that comment on the manner of writing, referred to as *style disjuncts* by Quirk *et al.* (1985).

The interpersonal function is concerned with the relationships that obtain among the participants in an event. In the written communicative event, we can speak of three participants: the writer, the reader, and the text; and two processes that shape the event: the writing and the reading. As a corollary, we can also speak of two situations: the writing situation and the reading situation. The two situations do not cohere, and the only entity that the two situations share is that of the text. The writing situation creates the text, and the text creates the reading situation. For the text to manifest authentically the writing situation, there must be a reciprocity among the participants, between the situations, and between participants and situations. The writer can achieve this by referring to himself, to the writing process, to the writing situation, to the reader, to the reading process, to the reading situation, and to the text. The writer and the reader interact with each other through the medium of the text. However, at the time the event (the text) takes shape, the status of the reader is only implied. Hence, the reader is not directly involved in shaping the event. The interaction, therefore, is envisaged, shaped, and initiated by the writer only. The reader enters the scene later and assumes the role of the implied reader as envisaged by the writer in the first place. If the statuses of the two — that of the implied reader and that of the actual reader — turn out to be incompatible, the result will be a breakdown in communication. The writer, therefore, is responsible for not only initiating the exchange, but also making sure that the reader follows it through to the

---

[8] In spoken discourse, prosodic features — stress, intonation, etc. — provide necessary prominence and emphasis. In written discourse, a similar kind of effect is produced by devices which are referred to as rhetorical prosodies in this study.

end. In Sinclair's (1983) terms, the writer needs to attend to the developing organisation of the text (***the autonomous plane***), and the ongoing interaction between him and the reader (***the interactive plane***). Also he needs to highlight, through textual features, the local as well as the global structure of the text, and, if necessary, to convey the same to the reader. The two planes are therefore not independent but reciproactive. It means that whatever the writer performs on the autonomous plane, he must, if necessary, convey the same to the reader on the interactive plane. At the same time, the writer may evince his own attitude towards what he performs on the autonomous plane: he may assert or evaluate, or he may comment and signal. The writer, therefore, has a three-fold task: initiating the exchange, making it successful, and deciding whether to present the propositions as fact or as possibilities. If they are presented as possibilities, they become something that can be argued about. According to Halliday:

> When language is used to exchange information, the clause takes on the form of a *proposition*. It becomes something that can be argued about — something that can be affirmed or denied, and also doubted, contradicted, insisted on, accepted with reservation, qualified, tempered, regretted and so on.
>
> *[Halliday, 1985:70]*

The function of the exchange can be broadly termed as that of ***inviting*** (cf. Halliday, 1985:68): inviting to accept, inviting to agree, inviting to do something, inviting to note, and so on. Even when the writer poses a question (rhetorical or not), the purpose is to invite the reader to join in the act of thinking, the act of discovery. The writer may present a proposition as likely or unlikely, desirable or undesirable by expressing it in modal terms, which then reflects "the writer's judgement of the probabilities, or obligations, involved in what he is saying" (Halliday, 1985:75). The interpersonal function, therefore, relates to the interaction between the writer and the reader. It is a truism that the nature of this interaction does not remain constant throughout the text. Grammatical variations generate shifts in tone and purpose, and the way they are executed may distinguish a competent writer from a non-competent one, or, for that matter, a native writer from a non-native one. Halliday's (1985:169) assertion that "Interpersonal meanings tend to be scattered prosodically throughout the unit" also points to such shifts.

Gregory and Carroll (1978) make a distinction between 'personal tenor' or 'degree of formality' between participants (p. 51) and 'functional tenor' or 'purpose' for using language in a particular situation (p. 53). While choices in person, voice and lexis realise personal tenor, choices in mood and modality determine functional tenor. According to Halliday (1985:169), "The interpersonal meanings are expressed ... by the 'Mood' block ... and by expressions of modality which may recur throughout the clause." The lexicogrammatical features that realise the interpersonal component in texts are personal pronouns, disjuncts, mood, modality, and evaluative modifiers (Halliday, 1978:144).

In addition, because the text has content, "we need an orientation in respect of *place*, *time*, *factuality*, and *participant relations*" (Quirk et al., 1985:1432). In fact, "There are numerous signals marking the identity between what is being said and what has been said before" (op cit.:1461). Some of the devices which help the writer achieve this reciprocity are known as ***metalinguistic comments*** (Quirk et al. (1985:618): *As noted above, In this paper*. Quirk et al. (1985) refer to some other such devices as *discourse reference* (p. 1461), and to others as *comment clauses* (*op cit.*:1112). Some of the *content disjuncts* (*op cit.*:620) and *conjuncts* (p. 643) perform a similar function. In this study, I refer to everything that performs a rhetorical function as ***rhetorical prosodies***. I include in rhetorical prosodies elements that realise the interpersonal function, and elements that comment on the text itself. These are what Leech (1983:15; also see Halliday, 1985:343) has referred to as ***interpersonal*** and ***textual rhetoric.***[9].

The interpersonal and the textual rhetoric are discussed below with instances from the two datasets. Paired examples (one each from the two datasets) are provided for exemplification.

---

[9] I am only borrowing these terms from Leech (1983); I am not using them in the sense Leech uses them.

3.3.5.1 Interpersonal Rhetoric

3.3.5.1.1 Mood

Mood refers to the way a verbal action is realised: as fact, command, wish, or a condition contrary to fact. Modern English has three moods: the indicative (for making statements and questions), the imperative (for commands and entreaty), and the subjunctive (for certain idiomatic expressions of wish, command, or conditions contrary to fact). Direct address to readers frequently involves interrogatives, or imperative constructions; however, indicative mood constructions may also be used to pose questions or issue commands, usually termed as the periphrastic imperative. Questions may be posed as a rhetorical device to introduce a new subject. Imperatives may be less or more interactive depending on whether or not they are directed towards the reader. Smith, Jr. (1985) names three types of imperatives: periphrastic imperatives (*Scientists must come to terms with* ...), first person plural imperatives (*Let us turn now to* ...), and direct imperatives aimed solely at the reader (*Note that* ...). Of the three, the last one is the most direct.

3.3.5.1.2 Modality

Modality refers to the expression of the writer's (and the speaker's) confidence or lack of confidence in what he states or asserts. As such, modality does not only include *modal verbs* but any expression that serves to hedge what the writer wishes to assert or propose. According to Halliday (1985):

> Modality represents the speaker's angle, either on the validity of the assertion or on the rights and wrongs of the proposal; in its congruent form, it is an adjunct to a proposition rather than a proposition in its own right.
>
> *[Halliday, 1985:340]*

When a writer asserts, he may present a proposition as true or untrue. Assertions are regulated by more or less the same conventions that govern communication in general. In terms of Grice's (1975) maxim of quality, a speaker must not say what he believes is false, or for which he lacks evidence. However, the scientist writer need not always comply with the second principle. He may not always have sufficient evidence to assert categorically. For example, instead of writing "the hornblendites and at least some hornblende in the remaining rocks are of igneous origin" he will write *it is likely that the hornblendites* ... [PAK-05]. The assertions we make depend on the evidence that is available:

> We make our statement sometimes with good, sometimes with moderate, sometimes with poor, evidence; which of these situations we are in need not be obvious to the hearer, and it would be cumbersome always to say explicitly.
>
> *[Urmson, 1963:225]*

As the writer must assert nonetheless, he has several ways to indicate to the reader what evidence he has for making the assertion. Again, the evidence may be either direct or indirect. The nature of the evidence will determine whether the writer should make a qualified assertion or an unqualified one. If the writer has strong evidence for the truth of his proposition, he usually indicates his commitment to the truth value of the proposition. A qualified assertion in such a situation may be construed as the writer's lack of confidence in his evidence. This may be the case, for example, if the evidence the writer has is not direct:

> By qualifying our conclusions and assertions in the ways we do, we authorize our hearers to put more or less faith in the assertions of conclusions, to bank on them, rely on them, treat them as correspondingly more or less trustworthy.
>
> *[Toulmin, 1958:90 f]*

Authors can express their opinions in either of three ways: a) by using modal verbs (*verbal modality*), b) by using alternative expressions which may be referred to as nonverbal modality, and c) by using metaphors of modality which, according to Halliday (1985:332), are "based on the semantic relationship of projection" as they are realised by "a separate, projecting clause in a hypotactic clause complex." To illustrate the three ways of expressing modal meanings, let us take the following three examples. The first (actual example from the native dataset) expresses the writer's assertion in metaphorical modality while the following two are variants of the first illustrating verbal and nonverbal modalities, respectively.

(29a) ***I believe that*** it is because of the overall symmetry of the system and general lack of block rotation that the restoration appears to be reasonable and successful. [NS-27]

(29b) ***It may be*** because of the overall symmetry of the system and general lack of block rotation that the restoration appears to be reasonable and successful.

(29c) ***It is probably*** because of the overall symmetry of the system and general lack of block rotation that the restoration appears to be reasonable and successful.

According to Halliday (1985:340), while the first gives prominence to the writer's own point of view by dressing it up as if the projected clause constituted the assertion, the other two make it appear as if it was not the writer's point of view. Halliday refers to the first as *explicit subjective* and to the other two as *explicit objective* (*ibid.*). The writer may use a modal adjunct instead of a projecting clause to hedge his assertion as in the following example:

(30d) ***Probably*** it is because of the overall symmetry of the system and general lack of block rotation that the restoration appears to be reasonable and successful.

The most common purposes for which writers elect to express their opinions may be: (1) assessment of probability/ possibility; (2) recommending or expressing obligation or necessity; (3) evaluation (comparison, approbation, disapprobation); (4) emphasis; (5) ability; (6) disputation, argumentation, and concession; (7) expected or unexpected outcomes (Adams-Smith, 1984:34-5). Thompson and Yiyun (1991), discussed at length in Chapter 2, also touch upon the use of modality which "as a major carrier of evaluation, would play an important part in conveying writer's stance" (p. 375).

Though a general agreement exists as what modality refers to, there is a good deal of terminological disagreement over basic concepts. What Halliday (1985) names *modalisation* (probability and usuality) versus *modulation* (obligation and necessity) is variously referred to as *epistemic* versus *deontic* modality (Palmer, 1979; 1986), *epistemic* versus *root* modality (Coates, 1983), *knowledge* versus *influence* modality (Young, 1980), *extrinsic* versus *intrinsic* modality (Quirk et al., 1985:219-221), and so on. Broadly speaking, "the term *modality* refers ... to a speaker's attitude or opinion about the truth of a proposition expressed by a sentence and toward the situation or event described by a sentence" (Simpson, 1990:66-7).

Epistemic modality is concerned with "the speaker's assumptions, or assessment of possibility, and, in most cases, it indicates the speaker's confidence or lack of confidence in the truth of the proposition expressed" (Coates, 1987:112). The epistemic modality ranges from *possibility* to *logical necessity* as illustrated in the examples below:

(30) When crystal symmetry restricts the motion of both cation and anion such as is observed in cubic pyrope, larger than normal bond distances and thermal motion ***may*** occur. [NS-05]

(31) Nevertheless, an attempt ***can*** be made here to outline a model for the magmatic evolution of the Chilas complex ... [PAK-24]

On the other hand, "Deontic modality ... is the modal system of 'obligation' as it is concerned with a speaker's attitude towards the desirability (or nondesirability) of certain action or event" (Simpson, 1990:67). Thus, meanings conveyed through deontic modality extend from *permission* through *obligation* to *requirement*. Deontic modality is rarely found in scientific writing, particularly permission modality; however, a few instances of obligation and requirement modality were found in the two datasets. In such instances, like the imperative mood, they serve predominantly to direct the reader (Example 34). The following examples from the two datasets illustrate the two types of modality:

(32) For this argument to have any significance, it ***must*** be assumed that the Gladstone-Dale relation is valid for structures with the degree of electron overlap found in silicates ... [NS-10]

(33) It ***should*** also be noted that in pulse 3 the order of samples which define the fluid compositional trend is mirrored exactly in the bulk rock K/Rb and Nb/Y values. [NS-19]

Though it is almost always possible to infer from the context whether the meaning is epistemic or deontic, there are certainly cases in which it is not possible to decide from the context which one is the intended or correct meaning. And there are other cases where the two meanings *blend* (Halliday, 1970:343) or *merge* (Simpson, 1990:68).

3.3.5.1.3 ***Comment Adjuncts*** ***(Attitude/Evaluation)***

Halliday (1977) includes attitudinal disjuncts in the lexicogrammatical features that realise the interpersonal component. Halliday (1985) further includes epithets in the interpersonal function as they too convey the writer's attitude. Examples are given below:

(34) ***Unfortunately***, such ambiguity is difficult to eliminate completely in comparing halides and chalcogenides as ligands. [NS-07]

(35) ***Interestingly***, whereas the strata older than this age are almost always cross cut by basic dykes, there is a sharp lack of basic dykes and sills in the younger (post Permian) strata (Pogue, personal communication). [PAK-12]

Evaluation is an essential feature of all texts. On a superficial level, it would appear that evaluation has nothing to do with academic research writing which is believed to be as factual, impersonal and objective; however, on a deeper level, we should be able to see indications of a writer's attitude towards the propositions being presented. The purpose of the writer in reporting his research is not simply to present facts and inferences based on experimental events, but also to convince his colleagues of the value of his research, and to persuade them to accept the new knowledge claims advanced by him (Latour and Woolgar, 1979).

3.3.5.2 Textual Rhetoric

I divide textual rhetoric into three categories: 1) those which serve discourse organising function, 2) those which help the reader interpret the discourse, and 3) those which comment on the manner/style of writing. Some of the textual rhetoric are also known as metalinguistic comments.[10]

The discourse organising or structuring comments are either reminding (retrospective) or informing (prospective)[11]. By recapitulating on something important that has gone before or by simply referring to it, the writer paves the way for carrying forward the discussion/argument. Similarly, he may apprise the reader of something that is to come, sooner or later. In addition to overtly indicating to the reader the development of the text and argument, the writer may also find it necessary to provide interpretive

---

[10] According to Francis (1994:89), metalinguistic comments or labels, in terms of her work on anaphoric nouns (1986), are nouns which "label a stretch of discourse as being a particular type of *language*. They are used by the writer to forge relationships which are located entirely within the discourse itself.; they instruct the reader to interpret the linguistic status of a proposition in a particular way" (original emphasis). My term, *textual prosodies*, includes anaphoric nouns as well as phrases and clauses which serve a similar purpose.

[11] Discourse organising/structuring comments are discussed by Francis (1994) under the term, *discourse labelling*. She identifies two types of labelling: advance and retrospective. Advance labels have an organising function: their function is to tell the reader what to expect. Retrospective labels, on the other hand, serve "to encapsulate or package a stretch of discourse" indicating to the reader "how that stretch of discourse is to be interpreted". A retrospective label also provides "the frame of reference within which the subsequent argument is developed" (p. 85).

comments (Crismore et al., 1993) in order to explain things and to indicate to the reader what he is about to perform. Accordingly, we can speak of the writer's indications of performing/executing author acts. The resulting classification is presented in Figure 7 below.

Discourse Organising Comments

1. **Discourse Entities:** (In this paper, In the following secton)
2. **Author Acts:** (As noted earlier/above, will be discussed later)
3. **Topic Shifting:** (*As for, In regard to*)

Interpretive Comments

4. **Discourse Labelling:** (This argument, This question)
5. **Performative Acts:** (We argue that, It is proposed that)
6. **Glossing/Exemplification:** (namely, for example, for instance)
7. **Logical Connectives**: (However, In addition, First, Second)

Stylistic Comments

8. **Manner/Style:** (Briefly, Strictly speaking)
9. **Expository:** (That is, in other words)

Figure 7: A Classification of Textual Rhetoric

What follows is a detailed discussion and illustration of each type exemplified with instances from the two datasets. Instances of textual rhetoric are ***highlighted*** throughout. The examples are from the discussion sections of the two datasets unless otherwise indicated. Two examples are provided for each type making a pair, one each from the two datasets. If an example does not form part of a pair, it means that it was not found in one of the datasets.

3.3.5.2.1 Discourse Organising Comments

This category includes three types of comments: reference to discourse entities, reference to author acts (retrospective and prospective), and topic shifting.

Referring to *discourse entities* comprises references to the entire text, (Example 36), to individual sections, (Examples 37, 38), and to tables and figures (Example 39). As the text is the only entity that the reader has at hand, such references have mainly organising function.

(36a) The methods presented ***in this paper*** are simple extensions of well established strain analysis techniques. [NS-30]

(36b) ***This paper*** presents the variation in the chemistry of magmatic and fenitic pyrobole as a result of fenitic fluids emanating from the carbonatite. [PAK-07; I]

References to sections (either with or without title) may be either prospective (37a) or retrospective (37b, 38):

(37a) ***In the following section***, we present results for a number of different rock-forming minerals. [NS-18]

(37b) As stated ***in the previous section***, the myrmekite in the AGC is typically found in the K-feldspar ... [PAK-13]

(38) The experimental data presented here are consistent with the ... transformation results of Fleet () referred to ***in the introduction***. [NS-02]

References to tables and figures occur in two forms: either part of the running text (Example 39) or enclosed within parentheses. The latter may occur either on their own or with directive verbs, for example, (***see Table 6***).

(39a) ***Figure 6*** is intended to illustrate the approximate scale ... of potential magma ascent rates ... [NS-03]

(39b) ***Figure 8*** shows that the pyroxenes from the volcanics of the Waziristan complex are of calc-alkaline type...[PAK-17]

Referring to Author acts includes verbs of the illocution type such as *discussed, shown, described, outlined*, etc. followed by adverbs of place, such as *above, below, under, here*. The adverb, *here*, was included in this category if it referred internally to the paper. Without exception, the adverb, *here* can be replaced by *in this paper*. A few examples are given below:

(40a) However, ***as shown above*** the effect of pressure is enhanced in multicomponent systems, whereas adiabatic gradients are not nearly as compositionally dependent. [NS-03]

(40b) As the alkaline nature of these pyroxenes has been ***ruled out above*** the volcanic arc affinity remains the only alternate origin suggested by this diagram too. [PAK-17]

(41) Other characteristics of these peridotites from Waziristan ... also support their island arc origin, along with the additional evidences from the related rocks ***discussed below***. [PAK-17]

(42a) Sphalerite, however, is common in rocks of the mine sequence, although not in the immediate vicinity of the retrograde textures ***described here***. [NS-14]

(42b) It is hoped that the field and petrographic aspects ***outlined here*** will provide a better understanding of the relationships amongst the constituent rocks of the Chilas complex. [PAK-24]

This class of textual rhetoric also includes expressions containing verbs, usually of illocution type, with temporal adverbs, such as, ***earlier, previously*** and nouns naming author acts. Their purpose is either to highlight the textual function of the immediate text environs or to indicate progression of the discourse. On the whole, in our data, they served the purpose of keeping the reader abreast of the development of the proposition, and to put him in the right perspective for the immediate line of argument. The following examples illustrate verbs followed by adverbs referring to earlier sections of the text in terms of chronology:

(43a) The composite crystal veins ***discussed earlier*** provide evidence to indicate that in some situations bedding plane-parallel thrusts may be initiated or reactivated by ... [NS-28]

(43b) ***As mentioned earlier***, the occurrence of ultramafic rocks at the present level of erosion ... can be attributed to ... [PAK-20]

(44) ***As indicated previously***, an increase in chloride concentration extends the range of stability of abhurite ... [NS-22]

The writers sometimes reiterated what was achieved in the preceding section(s) without explicitly referring to them. The purpose seems to prepare the reader for the impending line of argument.

(45) ***Having established that*** our calculations reproduce expected trends in bond distance ... *we can use the results to help in assigning* the NMR spectra of the F-bearing aluminosilicate glasses. [NS-07]

Example (45) contains both a retrospective and a prospective discourse marker. What the writer intends to do is based on what he has already done. Being the very first sentence of the discussion section, it not only serves to remind the reader of the foregoing account, but also announces what the writer is going to do with what has already been achieved.

Topic Shifting is an important device which writers need to employ now and again to indicate to the reader, in some way, that a new topic is being introduced. It becomes all the more important if the new topic is being introduced in the same paragraph. Failing to do so may result in confusion and, worse, misinterpretation, particularly if there are no other indications which may provide the reader with a clue. *Topic shifting* also helps the writer re-enter a topic already mentioned. In the following examples, the writers use *topic shifting* devices to indicate change of topic:

(46a) ***In regard to the third assumption***, adiabatic cooling must be less than the depression of the plagioclase liquidus caused by decompression. [NS-03]

(46b) ***As for montmorillonite***, it occurs in four special environments: in soil profiles, in basic chemical sedimentation, in bentonites (altered volcanic ash), and in hydrothermal veins. [PAK-16]

Quirk & Greenbaum (1973:289-290) refer to such phrases as ***transitional conjuncts*** which either mark a transition to a new stage in discussion or introduce a related topic. Other such expressions are *Let us now turn to ..., Regarding ..., To turn to ...*

3.3.5.2.2 Interpretive Comments

Discourse labelling refers to the act of naming a discourse act which the writer has just performed. The discourse act referred to may be found in the immediately preceding part of the text, consisting of either a single sentence or a number of sentences. Examples are given below:

(47a) ***This conclusion*** is supported by the oxygen isotope data of Wenner () ... [NS-15]

(47b) ***This interpretation*** is also supported by the An mole% of plagioclase vs. Mg# ... of the coexisting clinopyroxenes plot. [PAK-17]

A discourse label tells us how a preceding stretch of discourse is to be interpreted. In Example (47a), the preceding proposition is termed as *conclusion*, while in the second a preceding act is referred to as *interpretation*.

Performative acts were performed in two ways: either as personal active mostly with the personal pronoun 'we', or as impersonal passive with 'it' in subject position.

(48a) ***We assign*** this to Al fourfold, coordinated by bridging O, for which our molecular model would be S3 symmetry ... [NS-07]

(48b) ***We tend to include*** [sic.] the Chinglai gneisses exposed on the southern border of the Ambela Granitic Complex in this group on the basis of ... [PAK-12]

(49a) ***It is suggested*** that once the hydraulic fracture has occurred, the resulting lens of fluid will be driven along the bedding plane ... [NS-28]

(49b) ***It is proposed*** that the lowermost shale dominant zone represents the prodelta (marine) clay deposit ... [PAK-19]

An alternative construction to ***It is concluded*** or ***We conclude*** was also found. In such constructions, the corresponding noun was used to point out the performative author acts.

(50a) ***In conclusion***, it can be said that due to the high thermodynamic variance of the corona textures described, phase diagram considerations are difficult to apply. [NS-24]

(50b) ***In conclusion***, it is likely that the hornblendites and at least some hornblende in the remaining rocks are of igneous origin. [PAK-05]

The function of performative acts is interpretive as such acts direct the reader how to interpret the following stretch of discourse — as an argument, as a suggestion, as a proposal, or as a conclusion, etc.

Glossing/Exemplifying are expressions that explain or exemplify and are usually non-restrictive appositive phrases (Quirk & Greenbaum, 1973:278). By exemplifying and explaining, writers help readers grasp the appropriate meanings of problematic and vague elements in the text, thus aiding their understanding and interpretation of the text. In the systemic terminology, this is the conjunctive relation of appositive exemplifying elaboration (Halliday, 1985:303).

No defining and explaining glossing was found in the two datasets — maybe because experimental RAs are intended for specialists, usually, in the same field. Exemplification was found to be numerous. Phrases, such as, ***for example*** and ***for instance*** occurred either in the initial position or embedded within the sentence. Their formal latinate equivalent, *e.g.*, was abundant; as such they were not included in the analyses.

(51a) If entropies, ***for example***, in addition to enthalpies, are also to be constrained in the data extraction, the LSQ logic is still appropriate ... [NS-04]

(51b) Elsewhere, ***for instance***, in the part of the foreland basin exposed in India, there is a complete absence of amphibole in the molasse sediments ... [PAK-02]

Logical connectives are known as *conjunctive relations* in Systemic linguistics (Halliday and Hasan, 1976:226-270; Halliday, 1985:303-109). Expressed through conjunctive adjuncts, adverbs, and prepositional phrases, the conjunctives (Logical connectives, in this study) relate together text elements, such as sentences, parts of text and, most important, propositions. They are the means by which explicit cohesion is created. Connectives express a number of relationships. Halliday groups the connectives in three broad categories: elaboration, extension, enhancement with further categories within categories within categories (see Halliday, 1985:303-309). The most common relationships that are expressed through connectives are those of addition, contrast, causality and temporality which can be further divided into more specific categories.

Characteristically, the connectives are not syntactically integrated elements in the clause; they are rather peripheral to it. A clause or a sentence need not have a connective for establishing a relation with a preceding or a following clause or sentence. The relation already exists, but may not be obvious to the reader. The connectives serve to make that relationship obvious so that the reader could interpret it in accordance with the writer's intended meaning. As such, they have a specific role to play in the textual component of metatext. However, there are problems.

Halliday (1985) refers to an ***internal*** and an ***external*** interpretation of the temporal connectives:

> Many temporal conjuctives have an 'internal' as well as an 'external' interpretation; that is the time they refer to is the temporal unfolding of the discourse itself, not the temporal sequence of the processes referred to. In terms of the functional components of semantics, it is interpersonal not experiential time.
>
> *[Halliday, 1985:305]*

Martin (1983:2), too, recognises that the temporal connectives may express "either a relation between events in the real world or a relation between rhetorical acts within a text." The concepts of 'internal-to-text' and 'external-to-text' are somewhat problematical. According to Martin (1983):

> distinguishing internal from external ... relations remains a problem, probably because these relations encode the speaker's interpretation of the real world more so than his perceptions of relations in the world.
>
> *[Martin, 1983:37]*

But it is easily understood in terms of the experimental research article if we accept that the RA is a report of an activity (study, investigation) that happened prior to the writing of the report. The report, which is the text itself, is thus the internal domain, while the activity (comprising, maybe, several processes), is the external domain. Any reference to the activity as a whole or to any process within it is then external to the report.

Consequently, it would appear that some connectives (or some manifestations of them) do not come under the purview of metalinguistic comments. But the problem is not insuperable. Let us take the following examples:

(52a) Spratt (1987), in a detailed analysis of ... acknowledged and addressed these problems. ***First***, she documented that ... ***Second***, by microscopically determining the orientation ... she was able to calculate and remove ... [NS-30; Introduction]

(52b) According to Allen () and Krauss & Middleton (), higher interconnectedness of sandstone bodies results in ... ***Next***, in-channel flow can erode the overbank fines and deposit interaformational conglomerates. [PAK-08; Discussion]

(53a) Our experimental procedure involves three assumptions ... ***First***, decompression rates and intervals are ... ***Second***, heat loss is insignificant compared with ... ***Third***, over the pressure intervals considered, adiabatic decompression is nearly isothermal ... [NS-03; Discussion]

(53b) We use these equations to calculate HR ... ***Next***, we discuss whether the individual HR brackets ... should be used. [NS-04; Method]

In examples (52a) and (52b), the connectives establish “the temporal sequence of the processes” in the real world or external to the ***current*** text (if by ‘external’ Halliday means ‘the real world’), while in examples (53a) and (53b), the same connectives serve to establish “a relation between rhetorical acts within [the] text.” The context clearly indicates whether a temporal connective should be interpreted as internal or external.

3.3.5.2.3 Stylistic Comments

In this category of textual rhetoric, I include style disjuncts such as *briefly, strictly speaking*, etc. and expressions which rephrase or restate what has already been stated, such as *that is, in other words*, etc. Such phrases (and clauses) represent the writer’s comments on the style/manner of writing. In the systemic linguistics, some of these expressions come under the conjunctive relation of elaboration: expository apposition, and clarification. Halliday (1985:303-304) has identified seven types of clarificatory expressions. According to him, such elements do not 'simply restate but reinstate, summarise, make more precise or in some other way clarify for purposes of the discourse' (p. 304). Two examples are provided below:

(54) ***In a strict sense***, line-length balancing of cross-sections is a theoretically unsound technique even in cases where the folds involved are isometric. [NS-29]

(55) ***That is***, where c equals 2.26, the left side of equation (1) becomes (n+1)(n-1) / 6(n+1) = (n-1)/6 ... [NS-10]

As the main purpose of rhetorical prosodies is to help the reader organise, classify, interpret, evaluate, and react to propositional material (Vande Kopple, 1985), comparison of discussion sections from the two datasets on these accounts will show how interactive the NSE and the Pakistani discussions are with respect to the reader.

3.4 Statistical Treatment

In cases wherein some kind of frequency counting is involved, such as frequency of different theme types, frequency of rhetorical prosodies and relative lengths of moves in words, the chi-square (χ^2) test is used to see whether or not the observed differences are significant at 0.01 significance level. For each chi-square test, the contingency tables are provided. Also in the method section of the relevant chapters, the detailed statistical design is presented listing the hypotheses, dependent variables, type and levels of measurement and significance level. Further details are given in the relevant chapters.

Let us now turn to an analysis of the *macro-movement* of the geology RA introduction, using the *CARS* model, and see whether the NSE and the Pakistani RA introductions are different from one another in any significant ways.◆

CHAPTER 4

Aspects of RA Introductions

4.0 Introduction

The purpose of this chapter is two-fold: (1) to evaluate the *CARS* model to see whether or not it adequately captures the rhetorical organisation of the geology RA, and (2) to discover differences in the rhetorical organisation of the Pakistani RA introductions *vis-à-vis* the native RA introductions. Deficiencies (if any) are discussed from the point of view of their adverse effect on the rhetorical import of introductions. The acronym, *CARS*, stands for *Create a Research Space*. The model is based on three broad needs that the researcher should address in his introduction: to establish the significance of the research to be reported; to 'situate' the research in terms of that significance; and to show how the research will hold its own in the field as a whole. Swales, accordingly, divides the introduction into three broad Moves that make up the *CARS* model (see Figure 8 below).

I have assigned decimal numbers to the steps for ease of reference in the discussion that will follow. Thus Step 3.3 would mean STEP 3 within MOVE 3. This study proposes to answer the following questions.

1. Do the geology experimental research articles, in general, conform to the IMRD structure which is claimed to be the logical structure of scientific RAs? Do the native (NSE) and the Pakistani RAs differ in this respect? And if yes, are the differences statistically significant?

2. Do the geology RA introductions conform to the rhetorical structure as suggested in the ***CARS*** model (Swales, 1990)? And do the NSE and the Pakistani RA

introductions differ in the employment and order of moves as proposed in the model? If yes, are the differences statistically significant?

MOVE 1:	**Establishing a Territory**	
	Step 1.1	Claiming centrality
and/or	Step 1.2	Making a topic generalisation
and/or	Step 1.3	Review of previous research
MOVE 2:	**Establishing a Niche**	
	Step 2.1a	Counter claiming
or	Step 2.1b	Indicating a gap
or	Step 2.1c	Question raising
or	Step 2.1d	Continuing a tradition
MOVE 3:	**Occupying the Niche**	
	Step 3.1a	Outlining purposes
or	Step 3.1b	Announcing present research
	Step 3.2	Announcing principal findings
	Step 3.3	Indicating structure of RA

Figure 8: A *CARS* model for article introductions (Swales 1990:141).

Based on an earlier study (Rahman, 1991), it can be hypothesised that the *CARS* model will not account for some of the features found in the geology introductions, for geology is one of those disciplines that have received no such attention. Of the 40 such studies that Swales (1990:131-132) lists, none deals with the geology research article. Discrepancies and differences are therefore expected.

4.1 Materials and Method

In order to answer the research questions posed above about the logical divisions of the geology RA and the rhetorical organisation of the geology RA introductions, every RA in the two datasets (30 each) was analysed for IMRD structure, and the Moves and Steps as proposed in the *CARS* model were manually marked in all the introduction sections. The presence (or absence) as well as the order of the Moves (and Steps) proposed for the section were noted. For the purpose of this study, a Move is defined as 'a discourse unit which carries the action forward' (cf. Stenström, 1994:36). To elaborate on this definition, I borrow the notion of text structure as *an* *activity structure* from Lemke (1988) to which he assigns two kinds of meanings: the ***dynamic*** and the ***synoptic*** (p. 158). According to Lemke:

> More precisely, the *dynamic* meaning of an action is its meaning in the context-up-to-now ... at which point it has a further *meaning potential* contingent on the possible actions that may follow it within the same activity structure. When an activity structure has been, at least potentially, completed, all its constituent actions are *retroactively* assignable their *synoptic* meanings in the completed structure.
>
> *[Lemke, 1988:158; original emphasis]*

And again:

> The *synoptic* meaning of an element derives from our construing it as a particular functional unit in a particular structure. This assumes that we have a completed structure of reference (even if itself ambiguous), i.e. that we know which GSP [generic structure potential] is relevant. But *dynamic* meanings occur on the way to a completed structure.
>
> *[Lemke, 1988:161; original emphasis]*

A move, then, accordingly, can be construed as a *functional unit* representing an action (or bit of text) in a particular completed *activity structure* (or genre) which acts as a reference point for the move. The *synoptic* meaning of a move depends on its function within the *dynamic* meaning activated up to that point. Every move, then, acquires some *meaning potential* for possible ensuing moves.

A move may also have co-functional sub-units, often termed *acts* (or steps, as in the *CARS* model). The relation between a move and its acts is the same as that between a genre and its moves: what moves are to genre, acts are to moves. As such, whereas the communicative purpose of an act is subservient to that of the move it is part of, that of the move is subservient to the overall communicative intention of the genre. We can, therefore, say that there exists a 'homogeneous relation' between these 'co-classed units' (Lemke, 1988:160).

The act, being the smallest interactive unit, signals what the writer intends to communicate (Stenström, 1994:30). Acts can thus be identified by the presence of lexical and linguistic elements, also known as discourse markers[1], which signal the onset of an act. This is particularly true of acts which are move-initial. Although such signals are overt indicators of the onset of moves, they are not always reliable. It is also essential to consider their function in the overall dynamic meaning, and its relation, ideational as well as rhetorical, to the immediate context. For example, on linguistic and synoptic considerations, the following passage appears to be an instance of Move 2, but a closer look and a consideration of its communicative purpose, its role in the making of the overall dynamic meaning, and its relation to the context reveals that it cannot be Move 2:

> One interpretation of coarse sieve textures similar to those in Figure 1 is rapid skeletal growth resulting from undercooling (). However, melt inclusions are commonly elongate, parallel to, or abutted against polysynthetic twin planes (Fig. 1) or they cut boundaries between individual crystals in glomerocrysts. [NS-03]

The adversative, *however*, makes sentence 2 look like a Move 2, but this inference may be easily ruled out by relating it to the preceding and the following sentences. Here, the authors are presenting an interpretation of coarse sieve textures in respect of the texture of their own Figure 1 which they have already extensively interpreted in the previous paragraph. These sentences form part of a very long Move 3 (*Occupying the niche*). It was on the basis of such considerations that a few *establishing a niche* Moves, embedded in Move 3, were recognised in the Pakistani sample. Only one example is provided here as others are presented in the next section:

> This paper is an attempt *to extend the same relationships* to the rocks of the northern Gandghar Range. [PAK-09]

The italicised clause of the sentence may be termed as Step 2.1d, that is continuing a tradition of extending knowledge in other directions. It is necessary to point out here that no other Move 2 occurs in this introduction.

A Move may be realised by a clause, a sentence, or a number of sentences. The following examples illustrate Move 2 in the three forms:

---

[1] According to Redeker (1990:372), "A discourse marker is a linguistic expression that is used to signal the relation [ideational, rhetorical, or sequential] of an utterance to the immediate context." According to this definition, a number of lexical expressions, such as *In this paper*, may also be considered discourse markers.

(1) There have been many studies of ammonium in different types of rock, including sedimentary (...), igneous (...) and metamorphic (...), **but pyrochlastic rocks have not yet been investigated.** [NS-11; clause]

(2) An important component of the complex so far undescribed, however, is the inclusions of intermediate to felsic composition which are contained in both the granites and syenites. [PAK-14; 1 sentence]

(3) The relative importance of submarine hydrothermal activity associated with seamounts is unknown. However, in terms of net crustal cooling, net amount of seawater reacted with crustal rocks, and potential for creating seafloor sulfide deposits, seamount could play an important role in global budgets (...). [NS-17; 2 sentences]

(4) So far, the entire Waziristan igneous complex has been labelled as an ophiolite complex (...), neglecting the significance of dacites (...). Such an association is, however, not very typical of oceanic crustal environment. Rather, it is indicative of supra-Benioff zone igneous activity (...). [PAK-17; 3 sentences]

These are examples of Move-2 (*Establishing a niche*) occurring in one segment. There are also examples in which a Move is interrupted by another move, but resumes after the interrupting Move/Step. Sometimes such interruptions are sustained over a large stretch of the text, while in other cases, they are very short. Some Moves may be very long, stretching over paragraphs. The literature review is one such Move in the introduction section.

H_0 There are no differences in the length of moves in the geology RA introductions written by native and Pakistani geologists.

H_1 There are differences in the length of moves in geology RA introductions written by native and Pakistani geologists.

Significance level? .... $p < 0.01$

Design

Dependent variable(s)? .... Length of moves
Measurement? .... Number of words Tally
Independent Variable(s)? ... ± Native Speaker of English
Measurement? .... Nominal, 2 levels
Independent or repeated? ..... Independent

Other features? .... Intact class

Statistical procedure? .... Chi-square

In order to compare the Pakistani RA introductions with the NSE for quantitative differences, such as length of Moves, six introductions each from the two datasets that had all the three Moves were randomly selected (as described in detail in Chapter

3). Parenthetical citations were disregarded when counting the number of words in each Move. The statistical design for this quantitative study is given below.

The following section presents the results from the three analyses.

4.2 Quantitative/Qualitative Findings

4.2.1 Geology RA and IMRD Pattern

Table 5 lists the number of NSE and Pakistani RAs that conform and do not conform to the IMRD pattern. As can be seen from the raw figures in table, a much higher proportion of Pakistani geology RAs did not conform to the IMRD structure. A Chi-square (χ^2) test reveals that the differences are significant ($\chi^2 = 13.82$, $df = 1$, $p < 0.001$).

Table 5: Number and Percentage of Native and Pakistani RAs that conform and do not conform to the IMRD structure.

IMRD PATTERN	Native		Pakistani	
	Total	**%**	**Total**	**%**
Conforming	19	63.33	4	13.33
Non-Conforming	11	36.67	26	86.67

($\chi^2 = 13.82$, $df = 1$, $p < 0.001$)

The fact that a very high proportion of Pakistani geology RAs do not follow the IMRD structure despite the fact that, like the NSE RAs, they are all experimental (based on field work, data and analyses) can be interpreted as the Pakistani geoscientists' non-familiarity with the IMRD structure. This interpretation is strengthened by the fact that the RAs in both the datasets deal with more or less similar topics within the same fields: mineralogy, structure, metamorphic geology, petrology, etc. As such, the Pakistani geologists' not following the IMRD pattern cannot be attributed to their writing on different topics in different fields.

4.2.2 The CARS Model and Geology Introduction

A detailed Move/Step analysis of the sixty RA Introductions revealed not only discrepancies between the model and the introductions but also deficiencies in the model itself though the three Moves were found to be a regular feature of almost all the introductions as claimed (86%). A complete Move/Step analysis of the introductions from the two datasets is provided in Appendix B-1 and B-2. Deficiencies in the model were mainly the result of its not accounting for some of the features found in the geology RA introductions. A regular feature of the geology introduction that the *CARS* model does not account for is reference to method/procedure and materials used. In as many as 9 NS (30%) and 10 PAK Introductions (33.3%), this feature was encountered, mostly at the end of the Introduction after Move 3 (*Occupying the niche*). A few typical examples are given below:

(5) For each species, we calculate the minimum-energy geometry *using standard self-consistent-field molecular orbital methods* (...). [NS-07]

(6) *Fifty five analyses* of garnet were performed on a *Cambridge Instruments GeoScan IV microprobe* operating in ED mode using accelerating voltage of 15KV (...). [NS-25]

(7) For the purpose of *heavy mineral separation and their chemical (microprobe) analysis, ten sandstone samples were selected* from the Hukni section around Shakardarra area (...). [PAK-02]

(8) Mineral compositions were determined with computer automated 2-spectrometer JCXA-733 electron microprobe, using wavelength dispersive system. [PAK-17]

This appears to be a standard feature of geology RAs, as it was found in both the NS and the Pakistani introductions, and in order to describe the genre structure of the geology RA, a Step to this effect needs to be included in the *CARS* model. Again, seven introductions (11.66%) had a different kind of opening from that described in the model. According to the *CARS* model, the RA introductions open with Move 1.1 which is termed as " Claiming centrality". Hence, it tends to be persuasive (Swales, 1981, 1990); however, six Pakistani (20%) and two NS introductions (6.7%) opened with a kind of background statement which was then followed by the Move 1.1 of the *CARS* model. It may be that the researchers deemed it necessary to provide background information in order to claim centrality. However, note that in the examples given below the sentences commencing Step 1.1 (highlighted sentences) can be conveniently placed at the beginning of the introduction (though somewhat debatable in the second example). Doing so not only immediately centralises the research but also makes it more persuasive and appealing:

(9) The early detritus shed by the Himalayan orogenic belt was deposited in the Kohat-Potwar foreland basin (Fig. 1) as a coarsening upward sequence, known as the Rawalpindi Group. The Rawalpindi Group is comprised of [sic] the Murree Formation lying unconformably over the Eocene limestone, and Kamlial Formation which has a transitional contact with the overlying Siwalik Group (). These sediments are characterized by a succession of transient depocentre which .... **[1.1]** ***The molasse sediments comprising the Rawalpindi and Siwalik Groups in the Kohat-Potwar fold-thrust belt during the last two decades have been the focus of multidisciplinary studies*** .... [PAK-08]

(10) The St. Francois Mountains of southeastern Missouri represent the best exposure of Precambrian basement in the midcontinent region of the United States. Over an area of nearly 1000 square kilometers, erosion has removed the Paleozoic cover and exposed a complex series of Proterozoic silicic volcanic and granitic plutonic rocks that are interpreted to be remnants of a series of collapsed calderas (...). **[1.1]** ***The Butler Hill-Breadtray granite is the largest pluton exposed in the St. Francois Mountains complex*** (Fig. 1). This pluton is interpreted to have formed as a subvolcanic massif that crystallized beneath a cover of its own volcanic ejecta (...). [NS-15]

In the two examples, the background information is concerned with apprising the reader of some essential facts about the area where research fieldwork was done. In the second example (10), the sentence indicating Move 1.1 also marks the beginning of a new paragraph.

This background information was found in other positions as well, but it is not possible to describe its position with respect to Steps as the Steps themselves were often displaced. For example, in the Pakistani sample, background information occurred after Step 3.1 in one introduction (PAK-03) and after Step 1.3 in one introduction (PAK-10), but, in all three cases, the Steps themselves were front-shifted. In the native introduction, this background information was found after Step 1.1. (See Tables 6 & 7 below for an overview of the order of Moves/Steps in individual introductions.) In the two tables, the highlighted Steps are the front-shifted Steps. These are the steps which occur before their assigned position in the *CARS* model. As a consequence, they displace other Steps which then occur later than their assigned position in the *CARS* model. Such displaced Steps have been <u>underlined</u> in Tables 6 & 7. The Steps which are repeated, such as Step 1.3, are in bold ***italics.***

The concept of front-shifted, displaced, and repeat Steps is important for an understanding of a writer's rhetorical choice. It should be noted that front-shifting does not mean bringing a Step to the beginning of the Introduction; it means the occurrence of a Step earlier than its assigned position in the *CARS* model. Front-shifting of a Step may be considered a deliberate rhetorical choice by the writer. This choice may either displace (back-shift) another Step (e.g., NS-01 & PAK-04) or result in a repetition (interruption and resumption, to be exact) of the Step preceding the front-shifted Step (e.g., NS-07 & PAK-20). These are the simplest examples as double front-shifting and double displacement also occur.

As far as validity of the *CARS* model is concerned, only eleven native (36.7%) and eight Pakistani (26.7%) introductions had an exact fit. By exact fit I mean the introductions that had no front-shifted or displaced steps. Similarly, twelve NSE and twelve Pakistani (40%) had a less exact fit. In the less exact fit, I include introductions that had only one front-shifting or displacement. The rest (7 NSE and 10 Pakistani) departed from the *CARS* model radically. These introductions had double front-shifting or displacement (see Tables 6 & 7 below).

4.2.3 Differences in NSE & PAK Introductions

4.2.3.1 Absence/Presence & Type of Moves/Steps

It can also be seen from the tables that while all native introductions had a Move 2, as many as ten Pakistani introductions (33.3%) did not have the Move 2 (*Establishing the Niche*) at all. This is a very important finding because the absence of Move 2 may reflect not only on the writer's purpose but also on the legitimacy of the entire research venture. It appears that the Pakistani geologists do not 'situate' their research in terms of its significance in the field as a whole. They do not establish a research niche. And in four cases, this Move is delayed considerably and made part of Move 3:

TABLE 6: Order of Swalesian Moves/Steps in the Native RA Introductions

RA NO.	1.1	1.2	1.3	2.1	3.1	3.2	3.3	
NS-01	1.1	1.2	**2.1b**	<u>1.3</u>	3.1b			
NS-02	1.1	B	1.2	1.3	2.1a	***1.3***	3.1a	
NS-03	1.1	1.2	**2.1d**	**3.1b**	<u>1.3</u>	3.2		
NS-04	1.1	1.2	1.3	2.1a	3.1a	**3.3**	<u>3.1a</u>	
NS-05	1.1	1.2	**2.1b**	<u>1.3</u>	3.1b			
NS-06	1.1	1.2	**2.1b**	<u>1.3</u>	3.1b			
NS-07	1.1	1.2	1.3	2.1b	***1.3***	3.1b	M	
NS-08	1.1	1.2	**2.1b**	<u>1.3</u>	***2.1b***	***1.3***	3.1b	M
NS-09	1.1	1.2	1.3	2.1b	***1.3***	3.1a		
NS-10	1.1	1.2	**2.1b**	<u>1.3</u>	3.1b			
NS-11	1.1	1.2	**2.1b**	<u>1.3</u>	3.1a	***1.3***		
NS-12	1.1	1.2	1.3	2.1a	3.1a	M		
NS-13	1.1	1.2	1.3	2.1b	3.1b	M	3.2	
NS-14	1.1	1.2	1.3	**3.1b**	<u>2.1b</u>			
NS-15	B	1.1	1.2	1.3	2.1b	***1.3***	3.1a	
NS-16	1.1	1.2	**2.1d**	<u>1.3</u>	3.1a			
NS-17	1.1	1.2	1.3	2.1b	3.1b			
NS-18	1.1	1.2	1.3	2.1b	3.1b			
NS-19	1.1	1.2	---	2.1b	3.1b	3.2		
NS-20	B	1.1	1.2	1.3	2.1b	3.1b		
NS-21	1.1	1.2	1.3	2.1d	***1.3***	3.1b		
NS-22	1.1	1.2	1.3	2.1b	***1.3***	<u>2.1ca</u>	3.1a	
NS-23	1.1	1.2	**2.1b**	<u>1.3</u>	---			
NS-24	1.1	1.2	1.3	2.1b	3.1b	3.2		
NS-25	B	1.1	**1.3**	<u>1.2</u>	2.1b	***1.3***	3.1b	M
NS-26	1.1	1.2	1.3	2.1a	3.1a	3.2		
NS-27	1.1	1.2	1.3	2.1a	3.1b	M		
NS-28	1.1	1.2	1.3	2.1a	3.3			
NS-29	1.1	1.2	---	2.1b	3.1a	3.3		
NS-30	1.1	1.2	1.3	2.1ab	1.3	3.1b	M	3.2

Notes:

Bold	Front-shifted Step.	**B**	Background Information.
<u>Underlined</u>	Displaced Step.	**M**	Method/Procedure Move.
Italicised	Repeat Step.	**I**	Implications section.

TABLE 7: Order of Swalesian Moves/Steps in the Pakistani RA Introductions

RA NO.	1.1	1.2	1.3	2.1	3.1	3.2	3.3	
PAK-01	1.1	**1.3**	**3.1b**	(2.1a)	3.1b			
PAK-02	1.1	1.2	**2.1b**	1.3	3.1b	3.2	**M**	
PAK-03	1.1	**3.1b**	**B**	1.3	2.1a	***1.3***	3.1b	3.2
PAK-04	1.1	**1.3**	1.2	**3.1b**	2.1b			
PAK-05	**B**	---	1.2	1.3	---	3.1b		
PAK-06	1.1	---	1.3	**3.1a**	(2.1d)	3.1a	**M**	
PAK-07	1.1	---	1.3	2.1b	3.1a	3.1b	3.2	
PAK-08	**B**	1.1	**1.3**	**2.1b**	**B**	2.1b	3.1b	3.1b
PAK-09	**B**	---	---	1.3	**3.1a**	(2.1d)	**PR**	
PAK-10	1.1	**1.3**	**B**	1.2	2.1a	3.1a	**M**	
PAK-11	1.1	1.2	1.3	**3.1b**	**PR**			
PAK-12	1.1	**1.3**	1.2	2.1b	3.1b	3.2		
PAK-13	1.1	1.2	1.3	---	3.1b			
PAK-14	1.1	---	1.3	2.1b	3.1b			
PAK-15	**B**	1.1	---	1.3	2.1d?	3.1b		
PAK-16	1.1	1.2	1.3	2.1b	3.1b	**M**		
PAK-17	**B**	1.1	1.2	1.3	2.1b	3.1a	**M**	
PAK-18	**B**	1.1	**1.3**	1.2	---	3.1b		
PAK-19	1.1	**B**	1.3	---	3.1a			
PAK-20	1.1	**1.3**	1.2	***1.3***	3.1a	**M**		
PAK-21	**B**	1.1	1.2	1.3	2.1a	3.1b	3.2	
PAK-22	1.1	1.2	1.3	2.1b	3.1b			
PAK-23	1.1	1.2	---	---	3.1b	**B**		
PAK-24	1.1	1.2	1.3	**3.1a**	(2.1d)	**M**		
PAK-25	1.1	1.2	1.3	---	**3.2**	3.1b		
PAK-26	1.1	1.2	1.3	2.1d	3.1b	**M**		
PAK-27	1.1	1.2	----	2.1b	----	3.2	**I**	**PR**
PAK-28	1.1	**1.3**	1.2	---	3.1b			
PAK-29	1.1	1.2	1.3	---	3.1b	**M**		
PAK-30	**B**	**1.3**	1.2	---	---	3.1a	**M**	

Notes:

Bold — Front-shifted Step.
Underlined — Displaced Step.
Italics — Repeat Step.
() — Move 2 embedded in Move 3.
Bold RA No — RA has no Move 2.

B — Background Information.
M — Method/Procedure Move.
I — Implications section.
PR — *Previous Research* section.

(11) In this paper we use trace-element geochemistry to show that the Warsak granites, ***irrespective of their peralkaline or peraluminous character***, are a typical example of A-type granites (...). [PAK-01]

(12) The present study was carried out to map and perform ***further petrographic and geochemical study*** of the complex in order to determine .... [PAK-06]

(13) This paper is an attempt ***to extend the same relationships*** to the rocks of the northern Gandghar Range. [PAK-09]

(14) The present study is ***a further attempt to elaborate*** these aspects of the complex. [PAK-24]

As no Move 2 occurs in these four introductions prior to the deictic reference to the study, the last three may be considered as implicit indications of "Continuing a tradition" (Step 2.1d) whereas Example 1 appears to be in the nature of "Counter claiming" (Step 2.1a). However, the statuses of these four embedded Moves 2 remain debatable.

Another variation noted was the type of Move 2. Whereas twenty-one native introductions (70%) had Step 2.1b (*Indicating a gap*), only 10 Pakistani introductions (33.3%) had an explicit Step 2.1b. Similarly, while six Pakistani introductions (20%) had Step 2.1d (*Continuing a tradition*), only four NSE introductions (13.33%) had this type of Move 2. On the other hand, while four Pakistani introductions (13.33%) had Step 2.1a (*Counter claiming*), as many as seven NSE introductions (23.33%) had this Step. This comparison reveals that Moves 2 in the Pakistani introductions were mostly of the type of *indicating a gap* and *continuing a tradition* while in the NSE introductions, they were of the type of *indicating a gap* and *counter claiming*. One instance of *question raising* type Move 2 was also found in the NSE introductions.

Although in terms of the *CARS* model, an introduction is supposed to have only one type of Move 2, two introductions (NS-22 and NS-30) had multiple Move 2 (having more than one type of Step 2.1). No Pakistani introduction had multiple Moves 2 though one Pakistani introduction (PAK-08) had a repeat same Step 2.1b later in the introduction.

Move 3 (*Occupying the niche*) was found to be a regular feature of introductions from both the samples, and Step 3.1b (*Announcing present research*), noted in 20 NS and 20 PAK introductions, was the favoured choice. Step 3.2, *announcing principal* *findings*, was a rare feature, found only in three NS and six PAK introductions. Again, Step 3.3, *indicating structure of RA*, was found only in three NS introductions (NS-04; NS-28; NS-29). Moreover, no Step 3.3 (*Indicating Structure of RA*) was found in the Pakistani introductions while only two NS introductions had this step.

4.2.3.2 Order/Position of Moves/Steps

More often than not, Move 1 (*Establishing a territory*) was found to occur as one discourse unit with the three constituent steps (1.1, 1.2, & 1.3) following in succession (60% NS & 56.7% PAK). However, almost an equal variation was noted in introductions from both the samples. Twelve NSE and thirteen Pakistani introductions had a different Step order. However, the split of Move 1 in the two samples happened due to two different front-shifted Steps. In all but two of the nine such NSE introductions, the split was caused by front-shifted Move 2. On the other hand, in nine of the twelve such Pakistani introductions, the rift was caused by front-shifted Step 1.3. Thus, it can be said that the NSE geologists tended to establish a research niche quite earlier in the introduction (even before the literature review step: 10 examples) while their Pakistani counterparts appeared to delay it very late in the introduction (only two had a Move 2 before the literature review). Only eleven Pakistani and seventeen native introductions had the Move 2 in the assigned position. However, while as many as eight Pakistani introductions had it delayed considerably, only one NS introduction had it delayed to a comparable extent (NS-28).

TABLE 8: Front-Shifted, Displaced, and Repeat Steps in the two Samples.

	NATIVE SAMPLE			PAKISTANI SAMPLE		
MOVES	F-Shifted	Displaced	Repeat	F-Shifted	Displaced	Repeat
1.1	--	--	--	--	--	--
1.2	--	1	--	--	6	--
1.3	1	9	9	9	4	2
2.1	9	2	1	2	3	--
3.1	2	1	--	7	1	--
3.2	--	--	--	1	--	--
3.3	1	--	--	--	--	--
TOTAL	13	13	10	19	14	2

Table 8 provides an overview of front-shifted, displaced, and repeat Steps in the two samples. Differences are obvious. There is a good deal more Move 2 (*Establishing a niche*) front-shifting in the native sample (9) than in the Pakistani introductions (only 2). But the Pakistani sample has more front-shifting of the purposive step (Step 3.1). Thus, it appears that the Pakistani authors, instead of establishing a niche, tended to announce their purposes quite soon. Again, there was more front-shifting and less repetition of Step 1.3 (*literature review*) in the Pakistani introductions than in the native ones.

4.2.3.3 Onset/Realisation of Moves/Steps

Move 1 (*Establishing a Territory*) typically begins with what Swales (1990) calls *centrality claims* which are "appeals to the discourse community ... to accept the research about to be reported [as] part of a lively, significant or well-established research area" (p. 144). We have already noted that six Pakistani introductions had a kind of background information before the centrality claims step. This was noted only in two native introductions. Both groups of writers used wide-ranging strategies to claim centrality. A few examples are given below:

(15a) Post-Siwalik Quaternary sediments of the Peshawar valley have attracted the attention of *various geologists* ()... [PAK-16]

(15b) *There are several approaches* that have been used to elucidate the structure and kinematic evolution ... [NS-27]

(16a) The Warsak granites are amongst the earliest recognised peralkaline granites in N. Pakistan (). [PAK-01]

(16b) Oldoinyo, Lengai, situated in the Rift Valley of northern Tanzania, is the world's only active carbonatite volcano. [NS-21]

(17a) Heavy minerals are commonly used for the identification of source areas and ... [PAK-02]

(17b) Paleosoles are lithified weathering profiles that can provide information regarding the composition of the atmosphere at the time of weathering. [NS-12]

Move 2 (*Establishing a Niche*) is the most important move as it provides the basis for the entire research venture. The nature of this move makes it possible for the researcher to use wide-ranging linguistic exponents to establish a niche. For example, Swales (1990:155-56) lists as many as eight different categories that were actually used by writers.

The most common linguistic signal of Move 2 in our data have been the adversative, *however*, and the conjunction, *but* both in the initial and non-initial positions. These signals usually preceded references to ignored, unreported, unrecognised, undocumented, undescribed, and overlooked features, phenomena, sites, etc. However, references to limitations also occurred on their own. A few examples are provided below:

From Native Introductions

a) The distribution ... has not been previously described
b) but despite this, ... are either not recognised or not reported ..
c) but pyroclastic rocks have not been investigated.

From Pakistani Introductions

a) but the process is still not well understood
b) Subsequent studies, however, ignored ...
c) Hitherto, no extrusive equivalents ... have been reported.

Although most of such signals were commonly found in both the datasets, two instances of one kind of Move 2 signal was only found in the native introductions. Swales (1990) also does not mention this linguistic exponent in his eight categories:

a) However, there has been some considerable debate ...
b) there does not yet seem to be a consensus

Move 3 (*Occupying the Niche*) almost always had a deictic marker, demonstrative or personal (as in Example 19 below). Some started off with one deictic marker and later introduced the other kind as well (as in Example 20 below). Still a few other started in a different manner and introduced the deictic marker later in the Move (as in Example 18 below).

(18) ***We will start by showing how*** reversal brackets for an experimentally determined reaction may be converted into an enthalpy of reaction representing all the reversal brackets for the reaction. [...]. ***Discussion of these and related points is the focus of this paper. It will be shown that*** all of these concerns are unwarranted. ***We start with a consideration*** of the probability distribution of H-brackets corresponding to individual P-T brackets. [NS-04]

(19) ***The paper begins with a brief discussion*** of the ideas that have led to the association between high fluid pressures and thrusting and this is followed by a description of field evidence that support this. [NS-28; last sentence]

(20) Once these feasible fold geometries are defined from a theoretical standpoint, attempts are made to devise forms of analysis which allow these special fold geometries to be recognized amongst natural structures. This, in turn, allows conclusions to be drawn regarding the presence or absence of bed stretching associated with particular natural fold structures. [NS-29; last sentences]

In example 18, the sentence that signals Step 3.3 marks the beginning of a long discussion stretching over three paragraphs, comprising 22 sentences [18 sentences are omitted from the example], in which the authors point out concerns of the researchers about using reversal brackets. Next, the authors inform the reader of the focus of the paper (note deictic reference to the paper), allude to the outcomes (concerns are unwarranted), and then apprise the reader of the first point to be discussed. Example 19 is much simpler, as it begins with reference to the paper (*The paper begins*), and indicates what is to follow. The last example does not have a deictic reference to the paper as such, but the three sentences clearly point out how the paper is to develop: first, geometries will be defined; then, forms of analysis will be devised; and last, conclusions will be drawn.

According to Swales (1990), Step 3.1 is the obligatory step, as not having this step may create uncertainty in the readers' minds. The following explicit examples are from the Pakistani sample (the numbers in square brackets signify the number of occurrences):

1. In this/the present paper, we use/present .... [9]
2. The present study/paper .... [6]
3. This paper/study .... [4]
4. Present studies are/identify .... [2]
5. The main object of our present work .... [1]
6. The aim of the present study .... [1]
7. This ... occurrence is described ... in this paper. [1]
8. The emphasis in this paper is .... [1]
9. Based ... account of the complex is presented in this paper. [1]
10. We present here a detailed .... [1]
11. We report .... [1]
12. The author supports .... [1]
13. This requires a reinterpretation .... [1]

The following explicit examples are from the native sample:

1. This/The paper .... [5]
2. The present study/paper .... [4]
3. The aim/purpose of the present/this paper/study .... [3]
4. This study deals with .... [1]
5. We will start by ... Discussion of these ... points is the focus of this study. [1]
6. The principal goal ... of this study .... [1]
7. In this paper .... [1]
8. In the work presented in this paper .... [1]
9. This is essentially a reconnaissance study .... [1]
10. This work describes .... [1]
11. The results of the study .... [1]
12. Accordingly, this paper documents .... [1]
13. Here, we report .... [1]
14. This contribution documents .... [1]
15. In this contribution .... [1]
16. Also examined in this study .... [1]
17. We are currently interested in .... [1]
18. We have characterized .... [1]
19. ... we have calculated .... [1]
20. To test this hypothesis ... we performed .... [1]

As can be seen from the list above, the native geoscientists show a greater variety in signalling the start of Move 3 than their Pakistani counterparts. Pakistani Move 3 openings mostly tended to be of the first three kinds (63.3%). In the case of the native geologists, on the other hand, the first three kinds account for only 40% of all native Move 3 openings. However, this can be easily explained because the Pakistani sample not only comes from a single journal but also represents a very homogeneous group in terms of nationality of authors. Appendix B-1 and B-2 present the move/step division of each introduction in the two datasets in outline form.

4.2.3.4 Differences in Move Length

In order to compare the NSE and the Pakistani introductions in respect of length of Moves, two samples (six each) were drawn at random from the two datasets. It was necessary to adopt a workable procedure as there were some Pakistani introductions which either did not have a Move 2 (10) or had a doubtful Move 2 (4). It was, therefore, imperative not to choose such introductions as they would skew the results. Accordingly, these introductions were excluded from the draw. The NSE sample consisted of introductions NS-01, NS-07, NS-14, NS-16, NS-25, and NS-26, and the

Pakistani sample comprised PAK-04, PAK-08, PAK-12, PAK-16, PAK-22, AND PAK-26. Table 9 lists lengths of the three Moves in number of words in the two samples along with percentages.

TABLE 9: Lengths of moves in words in the Native and the Pakistani Introduction samples.

MOVES	NATIVE (n=6)			PAKISTANI (n=6)		
	Words	Mean	%	Words	Mean	%
MOVE 1	1260	210	51.96	1058	176	56.76
MOVE 2	499	83	20.58	232	37	12.45
MOVE 3	666	111	27.46	574	96	30.79
TOTAL	2425		100	1864		100

($\chi^2 = 49.41$, $df = 2$, $p < 0.001$)

As we can see from the table, the length of Move 2 in the native sample (20.58%) is much larger than that in the Pakistani sample (12.45%). On the other hand, the length of Move 1 in the Pakistani sample (56.76%) is much larger than that in the native sample (51.96%). A χ^2 test shows that this difference is significant ($\chi^2 = 49.41$, $df = 2$, $p < 0.001$). In order to find out whether the differences in the observed and the expected lengths in each case are also significant, we need a contingency table showing the values of the observed and expected lengths of each move for each sample.

Looking at Table 10, we find that the Pakistani geologists wrote a longer Move 1 than expected and a shorter Move 2 than expected. These differences are significant at 95% confidence level ($\chi^2 = 4.42$ with Yates correction for Move 1, and $\chi^2 = 41.17$ with Yates correction for Move 2). We can, therefore, reject the null hypothesis of no significant difference, and conclude that the Pakistani geologists would write a longer Move 1 and a shorter Move 2 as compared with their native counterparts.

Table 10: Contingency table of Observed (O) and Expected (E) lengths (in words) of the CARS moves in the Native and the Pakistani samples.

	NATIVE		PAKISTAN		TOTAL
	O	**E**	**O**	**E**	**O+O**
Move 1:	1260	1311	1058	1007	2318
Move 2:	499	413	232	318	731
Move 3:	666	701	574	539	1240
	2425		1864		4289

($\chi^2 = 49.41$, $df = 2$, $p < 0.001$)

4.3 Discussion and Conclusion

This study set out to answer three questions: (a) whether the geology RA followed the IMRD structure, (b) whether the geology introductions conformed to the rhetorical structure proposed in the *CARS* model, and (c) whether the Pakistani and the native datasets exhibited any differences in terms of questions (a) & (b). We also hypothesised that the native and the Pakistani introductions would not show any significant differences in move-length. We found that the geology RA, in general, does not appear to follow the IMRD pattern since a total of 37 RAs did not have the IMRD structure (61.66%). However, this non-conformity was more marked in the Pakistani dataset (86.66%) than in the NSE dataset (36.66%). We also discovered significant differences in the length of moves: the Pakistani geologists consistently wrote longer opening moves, whereas the native geologists wrote longer *establishing a niche* move. Further, we found that the *CARS* model did not account for some of the features found in introductions from both the datasets. This finding has clear implications for the *CARS* model.

Although the findings do not invalidate the *CARS* model, they, nonetheless, imply the need for a revision of the model. However, three paramount features of the *CARS* model are its lucidity, simplicity and manageability which should not be sacrificed for making it all embracing. No model, I believe, can account fully for the structure of discourse, for "discourse is a phenomenon of propensities" (Swales 1990:145). Thus keeping not only its basic structure intact but also retaining its simplicity and manageability, I venture to suggest the following changes.

First, I suggest that a new step be added to Move 3 so as to account for the description of methods, procedures, or materials found in sixteen introductions (26.7%) from both the native and the Pakistani datasets. Such passages usually occurred towards the end of the introductions, always after Step 3.1. Hence, a step to this effect can be added after Step 3.1. As the literature review, quite unexpectedly, was not found to be much repetitive (1.18 steps per introduction), my earlier suggestion (Rahman, 1991) can be disregarded. The suggestion was either to eliminate Step 1.3 (from pedagogical point of view, that is, to help forestall the possibility of learner' getting confused by seeing literature review everywhere while analysing introductions in practical sessions) or to include such literature review steps as extra steps in the remaining two Moves (from analytical point of view, that is for expert genre analysts). We can also extend Step 2.1b to include other ways of establishing a niche, such as by indicating a problem, or a need. The revised model should look as given in Figure 9 below.

The most important finding of the study was the absence of Move 2 (*Establishing a niche*) in as many as ten Pakistani introductions. Also some introductions were found to have a vague purposive Move 3 (*Occupying the niche*). This has clear implications for the attempts by Pakistani geologists to publish in international journals, for, usually, a vague purpose results in vague or dubious conclusions.

The two groups of writers showed distinct tendencies in many respects. Though it is not difficult to speculate what effect the Pakistani writers' rhetorical preferences will have on native referees and editors, it is not likely that their manuscripts will be rejected simply on this basis. If everything else turns out to be acceptable, they may simply be asked to do extensive and severe re-writing. However, if a writer carries his lack of focus and purpose through to the end, his conclusions are likely to be fuzzy, inconsistent or inaccurate which may lead to rejection. In order to avoid outright rejection, a scientist writer must have a clear focus, a singular purpose, and a lucid conclusion.

MOVE 1:	**Establishing a Territory**	
	Step 1.1	Claiming centrality
and/or	Step 1.2	Making a topic generalisation
and/or	Step 1.3	Review of previous research
MOVE 2:	**Establishing a Niche**	
	Step 2.1a	Counter claiming
or	Step 2.1b	Indicating a gap/problem/need
or	Step 2.1c	Question raising
or	Step 2.1d	Continuing a tradition
MOVE 3:	**Occupying the Niche**	
	Step 3.1a	Outlining purposes
or	Step 3.1b	Announcing present research
	Step 3.2	Describing Methods/Procedures
	Step 3.3	Announcing principal findings
	Step 3.4	Indicating structure of RA

Figure 9: The Revised *CARS* model for Article introductions

It will be seen in the next chapter whether the Pakistani writers exhibit similar preferences and tendencies in their discussions, too, and if they do, what effect they will have on the overall acceptability and readability of their research articles.◆

CHAPTER 5

Aspects of Geology RA Discussions

5.0 Introduction

The purpose of this chapter is to analyse the RA discussion section to help evolve a model for it. In spite of its importance, the discussion section has not received as much attention as the introduction. We do not as yet have a model for it that may be considered comparable to the *CARS* model. This chapter also aims to validate and consolidate the findings from the last chapter by comparing the discussion sections from the native and the Pakistani samples for rhetorical differences and rhetorical preferences. A study by Gosden (1992) shows that, on the whole, manuscripts submitted by non-native scientists to international journals suffer from inadequate discussion of findings for interpretation and valid generalisations. That is, the non-native scientists do not draw valid conclusions, or macroproposition, from their findings that may be seen as answering the research question(s) posed in the introduction section. A comparison of the relevant parts (Moves) of the introduction and the discussion section should reveal whether the discussions written by Pakistani geologists also have the same problems as reported by Gosden.

5.1 Materials and Method

A similar method was adopted for the present investigation as followed for the analysis of the introduction section. However, the study reported in this chapter is bottom-up rather than top-down. Although the discussion sections in the two samples were clearly author labelled, yet three problems were encountered:

1. The presence of an additional *conclusion* section.
2. Discussion and conclusion subsumed into one section.
3. Results and discussion as one section.

In addition, there was the minor problem of whether or not to include sections that have been labelled differently — such as Implications or Interpretations. After some thought, it was decided to accept sections labelled as 'Implications, and 'Interpretations' as legitimate discussion sections. It was also decided to include all separate conclusion sections, in the analyses and let the results decide whether or not they may be regarded as parts of the preceding discussion sections. The last problem was the most difficult to solve. However, noting that the discussion sections most often include a summary of major findings (see Hopkins & Dudley-Evans, 1988; Weissberg and Buker, 1990), we decided to include 'Results and discussion' sections in the analysis.

First, all the discussion sections comprising the two samples (30 each) were analysed for moves. Here again, a move (as in Chapter 4) is understood as a *functional unit*, having both a *dynamic* and a *synoptic* meaning. Second, the moves thus identified were grouped into larger units according to function. After some refinement, the identified moves evolved into a model, which then served as a point of reference for the comparative/contrastive study reported here. Appendix C-1 and C-2 present the move structure of all the discussion sections in outline form.

In order to find out whether the Pakistani geoscientists, like other non-native researchers as reported by Gosden (1992), also underplayed the importance of discussing their findings (Move 2 in the proposed model), the relative lengths of the three Moves (as proposed in the model) in number of words were compared. For this purpose, six discussions each from the two corpora that had all the three Moves were randomly selected (20% of the total discussions in the two corpora). Parenthetical citations were disregarded when counting the number of words in each Move. The statistical design for this quantitative study is given below.

For qualitative comparisons, a different procedure was adopted. It is a known fact that the RA discussion section seeks to answer either one or more research question(s) or to fill the gaps and fulfil the needs indicated in the introduction (in Move 2 of the *CARS* model). Unless the research question(s) is/are clearly answered, the entire research is liable to be labelled as invalid. The NSE and the Pakistani discussion sections are, therefore, analysed for ***macroproposition*** (main conclusion) and whether it answered the questions explicitly or implicitly.

H_0 There are no differences in the length of moves in the geology RA discussions written by native and Pakistani geologists.

H_1 There are differences in the length of moves in geology RA discussions written by native and Pakistani geologists.

Significance level? $p < 0.01$

Design

Dependent variable(s)? Length of moves
Measurement? Number of words Tally
Independent Variable(s)? ± Native Speaker of English
Measurement? Nominal, 2 levels
Independent or repeated? Independent

Other features? Intact class
Statistical procedure? Chi-square

5.2 Findings and Discussion

5.2.1 Marking Rhetorical Acts

A total of fifteen acts were identified in the sixty discussion sections thus analysed. Following are very explicit examples of the fifteen acts. The linguistic items that determine the act have been emphasised throughout. The difference between act 3, act 7, and act 12 is that the first occurs before any findings are reported, the second, after findings are reported, and the third, after a general claim or hypothesis is made.

Act 1: ***Background information***

> *Granites are found in almost all the major tectonic settings*, including mid-oceanic ridges, island arcs, continental margins, and within plates (R).... [PAK-01]

Act 2: ***Methods/Procedures***

> (...) *we employed isothermal experiments* as an approximation of natural processes, as the effect of pressure must be at least several times that of the adiabatic gradient.[NS-03]

Act 3: ***Previous Research***

Morse (1980) provided a convenient review of pertinent experimental data regarding the relative effects of isothermal decompression and adiabatic cooling. [PAK-02]

Act 4: ***Reporting findings***

As anticipated, Fe-bearing octahedra modeled in tremolite or cummingtonite are larger than corresponding observed octahedra ... [NS-08]

Act 5: ***Interpreting Findings***

The reverse trends which are observed in the individual grain of pyroxene from Koga fenitized syenites *are interpreted as the result of* fenitizing fluids having different Na/K ratios, emanating from the carbonatites.... [PAK-07]

Act 6: ***Unexpected findings***

The slightly larger deviation of berryllonite might be caused by the inaccuracy of ÂD(Na2O) estimated from the polarizability of NaF in conjunction with a value of ... It might also be caused by ... [NS-05]

Act 7: ***Comparing with previous findings***

According to Allen (1978) and Krause & Middleton (1987) higher interconnectedness of sandstone bodies results in a slowly subsiding basin as a result of low preservation of the overbank fines due to slow burial.... [PAK-08]

Act 8: ***Ratifying previous findings***

These temperature constraints are in *excellent agreement* with our range of fluid-inclusion-based temperatures, 240±35°C. *We therefore concur* with other workers that ... [NS-17]

Act 9: ***Refuting previous findings***

Such Al^{vi}/Al^{iv} ratios of these pyroxenes and their crystallization prior to plagioclase *further contradict oceanic crust affinity* and favours an island arc origin for Waziristan igneous complex. [PAK-17]

Act 10: ***Counter claiming***

It is, however, kinetic factors and not thermodynamic stability that ensure long-term preservation of the marcasite structure ... [NS-01]

Act 11: ***General claim/hypothesis***

Thus, and as already suggested on the basis of petrographic similarities, *the Tora Tigga complex may be related to* the Chilas complex of Khan et al., (1989). [PAK-05]

Act 12: ***Claiming support for hypothesis***

This conclusion is supported by the oxygen isotope data of Wenner (1988), which suggests that the final temperature of re-equilibration of the alkali feldspar throughout much of the St. Francois mountains complex is > 250°C. [NS-15]

Act 13: ***Summarising major findings***

Three Precambrian palaeosols of differing ages from Australia and South Africa reflect resetting and alkali metasomatism well after the weathering events that produced the palaeosols... [NS-12]

Act 14: ***Indicating limitations***

It is not very clear whether the individual rock types are solely the products of differentiation in separate basic and acidic large magmatic chambers or ... [PAK-06]

Act 15: ***Recommending future research***

Rare earth and isotopic studies are needed to resolve these issues. [PAK-06]

As can be seen, the first three acts provide a kind of background information. Act 1 is concerned with, what may called, real world entities, events, or processes. Act 2 provides information about the methodology employed in the study, and act 3 gives background literature review. The next seven acts (Acts 4-10) are concerned with the findings — reporting, interpreting, comparing, ratifying, refuting, etc. And the last five acts (Acts 11-15) serve to generalise the findings by advancing a new hypothesis, claiming support, recommending future research, etc.

The fifteen acts can be conveniently categorised into three broad moves, corresponding to a three part functional division of the discussion section.[1] At the start of the discussion, the writer may elect to provide some background information before commencing reporting of the findings. It may be that some very specific background information needs to be provided which the writer could not give before (in the introduction). This usually involves expanding on the key points as stated in the introduction, particularly Moves 1 & 2 of the *CARS* model (*Establishing &*

[1] Dudley-Evans (1994:224) calls this "an overarching three-part framework" that he designates as *Introduction-Evaluation-Conclusion*. However, he does not utilise this finding to the full as done in this study. In his case, it appears to be only a passing remark whereas in mine, this division is pivotal.

Occupying the niche). I am calling this part (Move-1) ***Re-setting the Perspective*** as its function is no more than refreshing the memory of the reader, to prepare him for putting the findings about to be discussed in the right perspective. In other words, it helps to enhance the readers' understanding of the argument.

In the second part, the core of the discussion, the writer reports the findings. He has the option to report all the findings at once and then go on to interpret them or he may choose to report and interpret the findings one by one. Or, instead, he may choose a combination of the two. Whichever option he may choose, he will need to compare or contrast his own findings with those previously reported in the literature. However, the second option — of reporting and interpreting findings one by one — will engender a similar process of repeated comparing and contrasting, thus resulting in recycling. If there are very few findings to report, the choice is usually to report them and then interpret them. No recycling was therefore observed in very short discussion sections, such as NS-04 and PAK-01, to give only two examples. If there are any unexpected findings to report, the researcher usually gives an explanation for the same. I call this second move ***Discussing the findings***.

Having reported and interpreted the findings, the writer may move on to advancing a new hypothesis, or, based on his findings, may simply make a general deduction. This may be followed by claiming support from previous research for his standpoint. The researcher may then indicate limitations of his findings that can lead to his recommending future research. But this may not always happen. If several findings have been reported, the writer may first summarise the major findings before indicating their limitations and recommending future research. Major findings may also be summarised in a separate conclusion section. I call this move ***Generalising the findings***.

5.2.2 Evolving a Model

Before evolving the fifteen acts into a proper model, a few comments about their refinement are in order. Table 11 below shows the total and the mean frequency of the fifteen acts per discussion section as found in the sixty RA discussion sections (30

NSE and 30 Pakistani. A mean frequency less than 1 indicates that the act did not occur in all the discussion sections. The acts are arranged in three groups referred to above as the three logical strands of the discussion section, corresponding to the three broad Moves of the model that will evolve from these acts.

TABLE 11: Total and means (per section) frequencies of the Fifteen Acts identified in the native and the Pakistani RA discussion sections.

	Native Sample (N=30)		Pakistani Sample (N=30)		Both Samples (N=60)	
Acts	**Total**	**Mean**	**Total**	**Mean**	**Total**	**Mean**
1	**23**	**0.77**	**22**	**0.73**	**45**	**0.75**
2	9	0.30	4	0.13	13	0.22
3	**13**	**0.43**	**12**	**0.40**	**25**	**0.43**
4	**92**	**3.07**	**69**	**2.30**	**161**	**2.68**
5	**94**	**3.13**	**70**	**2.33**	**164**	**2.73**
6	3	0.10	0	0.00	3	0.05
7	**50**	**1.67**	**29**	**0.97**	**79**	**1.32**
8	9	0.30	12	0.40	21	0.35
9	6	0.20	11	0.37	17	0.28
10	**16**	**0.53**	**9**	**0.30**	**25**	**0.42**
11	**47**	**1.57**	**47**	**1.57**	**94**	**1.57**
12	**15**	**0.50**	**12**	**0.40**	**27**	**0.45**
13	**10**	**0.33**	**9**	**0.30**	**19**	**0.32**
14	5	0.17	3	0.10	8	0.13
15	8	0.27	8	0.27	16	0.27

Of the first three acts which comprise background information, act 1 was the most frequent (0.75) while act 2 was the least frequent (0.22). Taking 0.30 as the cut off point, I decided not to include act 2 as a separate step in Move 1. As for the next seven acts, the most frequent acts were 4 (2.68), 5 (2.73), 7 (1.32), 8 (0.35), and 10 (0.42). Moreover, acts 4 & 5 occurred in close succession sometimes inseparable. As it is very unlikely for the two similar acts, ratifying previous findings (act 8) and refuting previous findings (act 9), to occur concurrently, they were merged to compose a single Step for the model. While acts 11 & 12 were frequent (1.57 & 0.45 respectively), the last three were not so frequent. However, acts 14 & 15 were kept as Step 3.3 in the model — act 15 (indicating limitations) because of its importance and explicitness, and act 14 because it usually necessitated act 15, recommending future research. The model that evolved thus is given below.

I prefer to use the word "Findings" rather than "Results" as the latter refers to outcomes of experimental nature only, while the former refers to the outcomes of observation, scrutiny, examination as well as experiments.

Move 1: Re-setting the Perspective
1.1 Providing Background Information
1.2 Referring to Previous Research

Move 2: Discussing the Findings
2.1 Reporting the Findings
2.2 Expanding on/Interpreting the findings
2.3 Comparing/contrasting with Previous Research
2.4 Ratifying/refuting Previous Findings
2.5 Counter claiming/Question raising/Indicating Problem/Gap

Move 3: Generalising the Findings
3.1 Making a General Claim/hypothesis/deduction
3.2 Claiming support for Hypothesis (Previous Research)
3.3 Indicating limitations & Recommending future research
3.4 Drawing conclusions

Figure 10: A three-Move model for the Discussion section

Thirteen native and fourteen Pakistani RAs had an additional section usually labelled "Conclusions". It was found to have two variations. It either summarised the findings discussed in the discussion section (6 NS & 11 PAK), or comprised the three Steps making Move 3 (7 NS & 3 PAK). While the former, being an adjunct, can be disregarded, the latter must be taken into consideration as it functions as Move 3.

The opening of the discussion had two variations. It depended on whether the author regarded background information as essential or not. The discussion opened with Move 1 (22 NS & 21 PAK) if background information was regarded to be critical, or Move 2 (9 NS & 8 PAK) if not. In the former case, the usual Step was 1.1 (14 NS & 18 PAK) while in the latter case, it was Step 2.1 (9 NS & 8 PAK). What follows is a detailed discussion of the Moves one by one.

5.2.2.1 Move 1: Resetting the Perspective

As already mentioned, Move 1 was the usual opening Move. It was found to be closely similar to the introduction, a recapitulation on what was said in the introduction (a brief mention of the purpose of the study, problem, hypothesis, or research questions), usually adding more detail, as shown in the following very explicit examples. Every example consists of two passages, the first from the introduction, the second from the discussion:

(1a) The Cu2Cl octahedra observed in copper oxysalt minerals are almost invariably distorted into a (4+2) arrangement because of the Jahn-Teller effect (R). [NS-01]

(1b) Tolbachite contains Cu2+Cl octahedra distorted such that there are four Cu-Cl equatorial bond distances [...] and two much longer Cu-Cl apical distances [...], a (4+2) distortion. This octahedral environment is a result of the well-known Jahn-Teller effect. [NS-01]

(2a) The Lorentz-Lorentz law has a theoretical basis, and has been used in a general way by a number authors, including McConnell (1965) and Anderson (1975), to demonstrate consistency of optical properties in minerals. [NS-10]

2b) The L-L law has a theoretical basis; it is expressed, following Lasaga & Cygan (1982), as [...]. Anderson (1975) developed the L-L law to include the effects of electron overlap [...]. Anderson's equation (17) can be expressed as [...]. [NS-10].

(3a) A restricted part of the internal zone of the Indian plate comprising Peshawar plain and lower Swat foothills in characterised by an assemblage of plutonic igneous rocks which define an alkaline igneous province in this region (R). The various igneous complexes of the province include ... and comprise a diverse assemblage of rocks including peralkaline to alkaline granites ... A phase of tholeiitic basic magma is closely associated, both in space and time, with the alkaline magmatic activity in the Peshawar plain alkaline province. [PAK-12]

(3b) Whereas the external zone of the Himalayan thrust fold belt is completely devoid of magmatic rocks, they are not uncommon in the internal zone.... The second phase is distinctly alkaline to peralkaline in chemistry and resembles closely with postorogenic A-type granites (R). These granites are typically distributed in a semicircle around the western, northern and northeastern fringes of the Peshawar plain. They are spatially associated with a suite of undersaturated to mildly oversaturated alkaline to peralkaline magmatism which gives rise to a diverse assemblage of rocks ranging from ... [PAK-12]

(4a) In northern Baluchistan the upper part of the Parh Formation (Cretaceous) shows evidence of widespread volcanic activity. [...]. These rocks, earlier referred to a the Bibai Formation (R) overlie the Parh Formation .... [PAK-23]

(4b) The Bibai rocks indicate significant volcanic activity in the northeastern Baluchistan towards the close of the Cretaceous (Campanian to Maestrichtian). [PAK-23]

In a few cases, if considered separately, the Move could easily qualify as an introduction section, as in the following example (superscripts indicate running sentence numbers in the particular sections). As such, Move 1 could be regarded as an introduction to the discussion section.

---

(5) [1]The origin of garnets in granitic rock and lithium pegmatites has long been problematical since many of these rocks were not intruded at the great depths commonly believed to have been responsible for garnet nucleation. [2]Their presence in granitic rocks has allowed some authors to constrain the petrogenesis of the host rocks by relating host geochemistry, field and textural relationships to garnet chemistry e.g., (R). [3]Until recently, this has not been the case for Li-rich pegmatites (R). [4]The Leinster garnet data are assessed firstly in terms of the partial melting model of a Li-rich protolith model favoured by McArdle and Kennan (R) and then in the light of the 'magmatic' model of Whitworth and Rankin (R) and Whitworth et al., (R). [NS-25]

A few other such moves referred to preceding section(s) as a point of departure for the discussion to commence. This occurred mostly in the RAs which did not have a Method and a Results sections:

(6a) [1]Having established that LSQ is an appropriate methodology for extracting thermodynamic data from experimentally bracketed equilibria, the power of LSQ in allowing the calculation of uncertainties in and correlations between the thermodynamic data can be reiterated. [NS-04]

(6b) [1]The petrographic and mineral chemistry data, discussed in the previous sections, is inadequate for a precise estimation of the P-T conditions prevailing during the metamorphism of the studied rocks. [PAK-25]

Even when the Move 1 occurred elsewhere in the discussion, it still exhibited these characteristic features. The purpose of Move 1, if it occurred elsewhere in the discussion other than the initial position, seemed to provide a point of departure, so to speak, for reporting and interpreting a new set of findings. Two examples are given below:

(7a) [29]The chemical composition of primary clinopyroxenes reflects the chemistry of host rocks (R). [30]In view of this, the clinopyroxenes have been previously used for discrimination of different palaeo-tectonic settings (R). [PAK-17]

(7b) [3]In favourable circumstances, there are few or no interfering lines ... [12]No other crystal can be used for this element, therefore, analysis must be attempted using ... [NS-16]

Very rarely, Move 1 was found to be repeated several times throughout the discussion. This happened when the RA dealt with different individual minerals, rocks, or phenomena, the writer taking them in turn. A very good example of this type of repetition was found in NS-18, dealing with TL spectra of several minerals.

In Move 1, the writer sometimes described the methods, procedures, techniques or data used in the study. As many as nine native and four Pakistani discussion sections had this feature. Four examples are given below:

(8a) [4]Estimates of the time taken for a given fraction (R) of pyrite to be produced from marcasite can be made using the activation energy and frequency factor obtained above. [5]A rate constant is derived from the Arhenius equation for the temperature of interest, and the time taken fro a given pyrite fraction (R) to be obtained is calculated from the following form of the Johnson-Mehl equation .... [NS-02]

(8b) [32]Because the results of the present study are being judged against results of 'bulk" analyses of homogenized powders, we have chosen to carry out microprobe analyses at 10 widely spaced locations on the glass chips and average these, rather than take 10 replicate analysis at a single (5 to 10m) point.... [33]This procedure, however, can be expected to reveal inhomogeneity on the micro scale. [NS-16]

(9a) [6]Obviously, for a precise determination of tectonic setting of magma generation for the Warsak and other granites in the Peshawar plain ... a two-fold approach is required: firstly, the chemistry of ... needs evaluation in order to ascertain the type of magma. [7]Secondly, radiometric age data are required in order to determine relationship between .... [PAK-01]

(9b) [13]If rocks are defined by a five mineral assemblage ... and [if] effective velocities (Vp, Vs) for these minerals are known, then the aggregate velocities (Vp, Vs) can be estimated for different rocks on the basis of Birch (1943) model given below. [PAK-26]

It has already been pointed out that the Introduction section contained such a description. A comparison reveals that in only two cases (one NS & one PAK) the discussion Move 1 expanded upon what was stated about the method or approach in the introduction section. In the remaining, no such duplication occurred. It may, therefore, be concluded that methods, techniques or data are referred to in either the introduction or the discussion, rarely in both. If a separate Methods/Procedures section exists, only those aspects of the methodology are mentioned in the introduction which the author thinks are distinctive of his study or which might hold the interest of the reader.

Move 1 also contained references to previous research or established knowledge which were almost always parenthetical. This was in marked contrast to similar steps in Moves 2 & 3 which were almost always reporting or integral.

5.2.2.2 Move 2: Discussing the Findings

Move 2, the middle, core part, consists of five steps. All the discussion sections invariably had all the steps. Moreover, this Move was found to be extremely cyclical (see Appendix C-1 and C-2 for this feature). As already pointed out, if the writer has more than one finding to report and if he chooses to report and interpret his findings one by one, the result is cyclicity. As such, the two related steps, Step 2.1 and 2.2, have been found to occur either in quick succession or simultaneously. It depends on how the writer elects to report his findings. The writer may report the finding, dwell on it for a while, and then interpret it, or he may report and interpret the finding at the same time within a single sentence. In the former case, reporting is elaborate, while in the latter, it is very brief. The following examples serve to clarify the point:

(10a) **16**Tables 3, 4 and 5 report the results of the QUICKSIT and STRETCH calculations on the DLS-adjusted structures. **17**The calculated coordinates are such that corresponding O-H-distances are consistently close (0.01Å) to 0.96Å which is the observed distance in tremolite. **18**Thus the calculated position of the hydrogen atom is strongly correlated with the position of the O(3) oxygen, but in such a way that the calculated O-H-distance is relatively insensitive to the position of O(3) oxygen.... [NS-08]

(10b) **8**The upper portion of facies PF1 consists of lenticular, coarse pebbly and non-pebbly medium-grained sandstone beds which are interbedded with shale beds. **9**This points to the interchange of quiet and high energy intervals (R) thus suggesting seaward deposition of these strata compared to the lower portion of facies PF1.... [PAK-03]

(11a) [8]Deformational textures are more commonly observed in pyrite rather than in the other sulphide minerals in the Renstrom ores, probably due to the higher relative strength of pyrite compared with the other sulphide minerals. [NS-23]

(11b) [8]The occurrence of lithofacies types Sh, Sl and Se (including Sm) are coupled with very coarse, pebbly and poorly sorted nature of the sandstones which suggest simultaneous deposition of both pebbles and sand perhaps with minor current fluctuations.... [PAK-11]

In examples 10a and 10b, Steps 2.1 & 2.2 occur in succession while in 11a and 11b, they occur simultaneously. I refer to the two types as successive and simultaneous only for convenience. The latter does not imply that the two Steps actually occur simultaneously (which is not possible); rather it suggests that the two Steps occur within a single sentence. Sometimes the two are so intertwined that it becomes difficult to mark the two separately. A third variation was also noted. Sometimes Steps 2.3, or 2.5 followed Step 2.1 instead of the usual Step 2.2. It occurred whenever the finding(s) was/were either too self-explanatory or necessitated an immediate comparison or contrast followed by ratification or refutation of previously reported findings. Moreover, if any unexpected findings were reported, the writer deemed it necessary to give explanation, reason or cause for the same. The following example serves to support this interpretation:

(12a) **[2.1]** A half-life for the solid-state transformation of marcasite to pyrite estimated from the above data at 473°K is 3 x 10^6yr, whereas at 433°K, calculation give a half-life of 13 x 10^9yr. **[2.4]** These half-lives show a consistency with the proposal of Murowchick and Barnes (1986). [NS-02]

(12b) **[2.1]** Similar concentration levels of these incompatible trace elements are also found in acid volcanic rocks exposed at the marginal contacts in the northwest, west and south of AGC. **[2.3]** These are thought to be related to AGC and are an extension of other volcanic and subvolcanic rocks of the Peshawar plain including those of the Shewa-Shabazgari (R). [PAK-14]

The majority of discussions from both samples (24 NSE, 18 PAK) had Move 2 cyclicity. Only very short discussions did not have any cyclicity; the longer the discussion, the greater was cyclicity. The most common repetition was that of Steps

2.1/2.2, which may be referred to as paired steps. Another example of paired steps is 2.4/2.5. But, as already mentioned, and as illustrated in examples above, this cyclicity can take various forms. In addition, we may distinguish between two patterns of cyclicity: First, cyclicity of the Move (more than two steps), and second, cyclicity of individual or paired steps. The following examples seek to illustrate the two patterns. Steps are given in the parentheses. Eight sentences have been omitted from the second example.

(13a) **[2.1]** The pebbles in strata of basal portion of the formation are in general rounded. Microscopic studies of these sandstones reveal the dominance of quartz and chert grains with subordinate proportions of feldspar and other minerals. These grains in general are texturally mature. **[2.2]** This textural and to a large extent compositional maturity of the pebbly sandstone beds of facies PF1 as well as composite bedding in lower portion suggests their deposition under high energy conditions (cf. Folk, 1974; Kumar & Sanders, 1976; Cotter, 1983). **[2.1]** The upper portion of facies PF1 consists of lenticular, coarse pebbly and non-pebbly medium- grained sandstone beds which are interbedded with shale beds. **[2.2]** This points to the interchange of quiet and high energy intervals (cf. Reineck & Singh, 1972; Kreisa, 1981) thus suggesting seaward deposition of these strata compared to the lower portion of facies PF1. (continues) [PAK-03]

(13b) **[2.1/2.2]** The Rb-Sr systematics of the Mt. Roe #1 paleosol indicate that the enrichment of K and Rb in the upper part of the profile, and probably the mild enrichment of Ca and Sr, occurred well after weathering took place.... **[2.3]** Recent whole-rock Rb-Sr data on samples of the Mt. Roe Basalt from a drill core located southwest of the town of Tom Price (Nelson et al., 1990) yield a scattered isochron corresponding to an age of 2,115 ±447 Ma, and having 87Sr/86Sri = 0.7061 ±0.0006.... **[2.1/2.2]** The similarity of the Sm-Nd ages of secondary riebeckite and the Rb Sr age of the Mt. Roe #1 paleosol suggests that they both reflect a period of low-grade regional metamorphism and metasomatism of the Hamersley and Fortescue groups, which only partly reset the Rb-Sr systematics of unweathered basalts.... **[2.3]** The weathering profile is thought to have formed approximately 2,200 Ma (Holland & Beukes 1990, and references therein); the Rb-Sr data indicate an age of 1,925 ±32 Ma.... [NS-12]

Although a number of discussions had more than one Step 3.1, the suggestion by Hopkins and Dudley-Evans (1988) that the writer always hypothesises at the end of each cycle is not supported by this evidence. The hypothesis, Step 3.1, was presented, if at all, after all the findings had been reported and interpreted. Its relative placement in the section is discussed below.

5.2.2.3 Move 3: Generalising the Findings

Move 3, the concluding part of the discussion, consists of four steps. Of these, Step 3.1 (*Making a general claim/hypothesis*) may be considered an obligatory step. If considered necessary, the writer may follow it with Step 3.2 (*Claiming support for hypothesis*). Usually, these two steps tend to occur in juxtaposition or succession:

(14a) **[3.1/3.2]** It seems quite reasonable that K-feldspar could have become ordered significantly during a major hydrothermal event, and Abdel-Rahman & Martin (1987) have recently documented just such a hydrothermal ordering of the K-feldspar in a Protozoic intrusive complex in southern Ontario. Therefore, we interpret the near-homogeneity of our data on structural state of the K-feldspar as further evidence for the pervasiveness of postcrystalization hydrothermal activity in the St. Francois Mountains Complex. [NS-15]

(14b) **[3.1]** However, the calcalkaline affinities and similarities of the suite to major plutonic rocks of island arc suggest that its origin was in some way related to subduction of an oceanic lithosphere during the formation of the Kohistan island arc. **[3.2]** This view is further corroborated by the similarity of mineral phases in the Chilas complex and island arcs plutonic rocks (Jan, unpublished data). [PAK-20]

As already pointed out at the beginning of this discussion, the steps comprising Move 3 may also form a separate "conclusion" section. An almost equal number of native and Pakistani RAs (13 NS & 14 PAK), had a conclusion section. Six NS and eleven PAK conclusion sections were excluded from consideration as they mostly summarised major findings, sometimes having numbered paragraphs. Though Step 3.1 was also found in a few Conclusion sections, it only duplicated Step 3.1 proper of the discussion section. The conclusions that were included in the analyses had Step 3.1, followed by Step 3.2. They were usually brief, rarely exceeding 10 sentences. Such concluding units are treated as Step 3.4 in the model and in Appendix C.

---

(15) **[3.1]** This investigation confirms that ... The pressure- and rate-dependence of the sliding stress and the microstructures of the fault zones are consistent with the hypothesis that the rheology of faults triggered by the olivine spinel phase transformation is controlled by grain-boundary sliding in the fine grained spinel of the fault zones.... **[3.2]** Iidaka & Suetsugu (1992) provided evidence that olivine exists metastably to a depth of at least 500km ... [NS-26]

Moreover, the Steps making up Move 3 can also occur before the onset of Move 3 proper (NS-07, PAK-06]. This usually happens when the writer has a number of findings to report and when he needs to report and interpret them one by one. As such, it becomes sometimes inevitable to indicate limitations (which may further prompt the writer to recommend future research to overcome the limitations). Making a general claim or hypothesis (Step 3.1) is therefore postponed. The discussion sections, therefore, closed with either Step 3.1 or Step 3.3. The following examples seek to illustrate this point:

(16a) **[3.3]** Although calculations using quantum mechanics on even simple gas phase molecules do not exactly match experimental results at the level of rigor used in this paper, and although the molecular models used cannot capture all aspects of the behavior of condensed phase species, **[3.1]** we nonetheless feel that semiquantitative estimates of trends in properties can be confidently obtained at this level. On the basis of our results, the five-fold-coordinated Al species ... probably has both F and O in its first coordination sphere, a probable molecular model being AlF3(OH)2, rather than AlF32, as previously thought.... [NS-07]

(16b) **[2.1]** A careful examination unravels that in certain sections the Budsari microporphyry shows volcanic flow phenomenon but in other sections a considerable amount of graphite is present; **[2.2]** a feature indicating it to be a combination of volcanic and sedimentary material and a possible member of the Sawabi-Chamia group. **[3.3]** Unfortunately, all the chemical data presented on the variation diagrams belong to the microporphyries of the Machi section. This microporphyry thus seems to be a differentiate of the aegirine riebeckite porphyry. In such a case the origin of the microporphyry at Budsari needs to be re-considered for detailed investigation. [PAK-06]

In comparison with the introduction section, the rhetorical organisation of the discussion section seems more fluid. It is already well documented in the literature that the discussion section has a less predictable structure than the introduction (Dudley-Evans 1986; Jingfu, 1987; Hopkins and Dudley-Evans, 1988; Dubois, 1989). For example, we have already seen that the Steps comprising the Moves can appear in different guises: in juxtaposition or in succession, etc. The most commonly found juxtaposition was that of Step 2.1 & Step 2.2. I also discovered in a few discussions (for example, NS-16) that before making a claim or raising a question, the writers indicated a problem or a gap:

(17) The trace analysis of Au is difficult in the present study. The FeK(III) line interferes with AuM on PET, hence it is necessary to use the AuL line on LIF. ... Although beyond the scope of the present study, modelling of the background would probably be the best way of dealing with this problem ... [NS-16]

As such, for practical reasons, we can refine our original model as in Figure 11. The refined model obviates the necessity of marking off the two steps (*reporting the findings* and *interpreting the findings*) which so often happen concurrently. The refined model can be used for both analytical and teaching purposes.

Move 1: Re-setting the Perspective

1.1 Providing Background Information
1.2 Referring to Previous Research

Move 2: Discussing the Findings

2.1 Reporting & Interpreting the Findings
2.2 Comparing/contrasting with Previous Research
2.3 Ratifying/refuting Previous Findings
2.4 Indicating a Problem/Gap
2.5 Counter claiming/Question raising

Move 3: Generalising the Findings

3.1 Making a General Claim/hypothesis/deduction
3.2 Claiming support for Hypothesis (Previous Research)
3.3 Indicating limitations & Recommending future research
3.4 Drawing conclusions

Figure 11: The Refined Three-Move model for the Discussion section

5.2.3 Comparing NSE & Pakistani Discussions

As not only occurrence but also variation and cyclicity of the Moves and Steps appear to be similar across the two samples, it is not possible to point out significant differences in the two samples. However, there are two ways — one quantitative and another qualitative — to compare the two samples for possible differences. The mean relative lengths of the three moves in the two samples may determine which move receives the most emphasis in the two samples. If a certain move receives similar emphasis in all the texts in a sample, it may prove important in determining the writing behaviour of that group of writers. And in the qualitative procedure, we need to look for key elements in discussion section from both samples relative to the introduction sections. These key elements invariably answer the questions posed in the introduction. Let us refer to such key elements as the ***macroproposition*** as they comprise the final, cumulative proposition of the total research venture. If a discussion section lacks a macroproposition, or if it is not made explicit, that discussion may be regarded as not fulfilling the purpose for which the study was undertaken. It may sometimes be construed as 'fuzzy thinking'. In the following section, the NSE and the Pakistani discussion sections are compared and contrasted on these two accounts.

5.2.3.1 Quantitative Evaluation

Table 12 below lists the lengths of each of the three Moves in number of words (discounting parenthetical citations) in six NSE and six Pakistani discussion sections selected for this purpose from the two corpora. The table also shows the length of each Move per hundred words as well as the ratio of the Moves to each other.

There are obvious differences between the native and the Pakistani discussions in terms of distribution of the three Moves. By being longer than the other moves in both samples (marginally true for the Pakistani discussions), Move 2 stands out as the most important move. For every word of Move 1 & Move 3 in the native discussions, there are 2 words of Move 2. However, in the Pakistani discussions, while still comparably longer than Move 3, it has a distribution equal to that of Move 1. This supports the view expressed in the beginning of this chapter that the second Move embodies the nucleus of the discussion. As can be seen from Table 12, Move 1 and Move 3 are equal in length in the native discussions; however, it is not equally true of the Pakistani discussions. The Pakistani authors appear to write longer openings, whereas the native authors dwelt longer on discussing the findings. The native writers seem to attach much greater importance to Move 2 than their Pakistani counterparts do.

TABLE 12: Relative lengths of Moves (in number of words), their percentage and ratio in the native and the Pakistani RA discussion sections.

MOVES	Native Sample			Pakistani Sample		
	Words	Percent	Ratio	Words	Percent	Ratio
1	1109	26.58	1	1363	39.37	1.9
2	2041	48.91	2	1386	39.93	1.9
3	1023	24.51	1	722	20.80	1
TOTAL	4173	100	-----	3471	100	-----

$(\chi^2 = 139.92, df = 2, p < 0.001)$

A Chi-square (χ^2) test shows that these differences are statistically significant (χ^2 = 139.92, $df = 2$, $p < 0.001$). Table 13 lists the observed and the expected lengths in words of each move in the native and the Pakistani RA discussions. We can see that the Pakistani geologists wrote a longer Move 1, and shorter Moves 2 and 3. A chi-square test shows the observed differences between the observed and the expected lengths for each move are significant at the confidence level set for this study (χ^2 = 94.39 with Yates correction for Move 1; χ^2 = 33.82 with Yates correction for Move 2; and χ^2 = 60.39 with Yates correction for Move 3).

We can, therefore, reject the null hypothesis of no significant difference, and can conclude that the Pakistani geologists appear to write longer introductory Moves (Move 1) than their NSE counterparts. As a consequence, the Move pertaining to the discussion and interpretation of findings (Move 2) and the one pertaining to conclusion and drawing generalisations (Move 3) tend to be shorter in the Pakistani discussions.

These findings are consistent with what Scarcella (1984) found in his comparative study of orientation employed by native and non-native writers in expository essays. His non-native writers wrote longer orientations than the native writers. The Pakistani writers gave longer background information, and they did not discuss their findings at as much length as the native writers. As it is a matter for the specialist to judge whether the Pakistani discussions are adequate, this point will be taken up in the chapter dealing with native reviewers' comments on Pakistani geology RAs. Now let us turn to a qualitative comparison of the two samples.

Table 13: Contingency table of Observed and Expected lengths (in words) of Discussion Moves in the Native and the Pakistani discussions.

	NATIVE		PAKISTANI		TOTAL
	O	E	O	E	O+O
Move: 1	1109	1350	1363	1122	2472
Move: 2	2041	1871	1386	1556	3427
Move: 3	1023	953	722	952	1745
	4173		3471		7644

($\chi^2 = 139.92$, $df = 2$, $p < 0.001$)

5.2.3.2 Qualitative Evaluation

If the introduction is viewed as the section posing the research questions or the problems, the discussion is the section in which the writer interprets the evidence (results) and provides answers to those questions. Thus, the questions or the problems posed in the introduction constitute the macroproposition or the nucleus of the introduction while the answers constitute the macroproposition of the discussion. The writer is as obliged to state explicitly the conclusions in the discussion as he is to pose his questions in the introduction. The statement of the problem or question may be regarded as the departure point while the answer to the question (conclusion) may be termed as the destination. According to Belanger (1982:1), "the structure of the discussion section is closely correlated to both the number and kind of research questions posed in the introduction section of the paper." It follows that the strength of the discussion section lies not only in explicitly answering the research questions but also in *fully* answering *all* the questions. And if a question remains unanswered, reasons should be provided along with recommendation for future research.

The following examples illustrate this interrelation between the introduction and the discussion sections. The titles are also given so as to provide the needed context for the examples:

(17a) **Title:** Tolbachite, CuCl2, the first example of Cu2+ octahedrally coordinated by Cl-

Introduction:

[14]Thus, the role of pseudo-Jahn Teller effect in controlling the geometry of mixed-ligands Cu2ø6 octahedra is not clear.

Discussion:

[7]Six examples of Cu2+Cl octahedra bond distances observed in mixed-ligand copper oxysalt-minerals is given in Table 2. [8]All such octahedra are (4+2)-distorted and the pseudo-Jahn-Teller effect is a controlling factor in determining the bond-distance distribution. [NS-01]

(17b) **Title:** Petrology and the grain size characters of the Pab sandstone of parts of the Loralai and Khuzdar districts of Baluchistan

Introduction:

[8]The present paper is intended to describe the petrology and grain size parameters of the Pab Sandstone and an attempt has been made to interpret the provenance and depositional environments based on petrology and grain size parameters.

Conclusions:

[8]Following conclusions may be drawn from the foregoing account of petrographic and grain size analyses:

[9]1) The Pab Sandstone (Late Cretaceous) is classified as quartz arenite, sublithic arenite and lithic arenite and derived from an acidic igneous and metamorphic terrain.

[10]2) On the basis of petrographic and grain size characters it may be suggested that the Pab Sandstone has been deposited in shallow marine (most probably beach) conditions. [PAK-10]

In example 17a, the problem indicated in the introduction (Step 2.1b) is answered in the discussion (Step 2.1). Usually, the research question is answered in Move 3, sometimes in a separate conclusion section. It may be that a question can be answered adequately only after several findings have been interpreted. In example 17b, the sentence from the introduction section (occurring as Step 3.1a) proposes to achieve two objectives. The numbered conclusion section clearly indicates that the objectives have been achieved. Note also a very high proportion of lexical repetition between the sentences taken from the introduction and the discussion sections.

Though it is easy to identify the questions as posed in the introduction (for the introductions are usually short and the questions may be found either in Move 2 or Move3), it may not be easy to locate the answers in the discussion sections, particularly if the discussion is very long or the questions posed in the introduction are vague. Such problems were usually encountered in the discussions from the Pakistani sample. Examples follow shortly.

The procedure adopted for the identification of the macroproposition in the discussion was as follows:

1. The research question(s) was/were located in the introduction. ('Question' refers to whatever the writer's aim in the study.)
2. The sentence or sentences appearing to be answering the questions was/were identified.

If nothing was found in a discussion section which could be considered as answering the question(s), that RA discussion section was considered to be lacking a macroproposition.

On the whole, two variations were observed in the way research questions were answered:

1. Question(s) answered as a summary/concluding statement:
   a. One sentence summary/conclusion (PAK-14).
   b. More than one sentence conclusion (13 NS, 14 PAK).
2. Answers spread out in the entire discussion.

The macroproposition stated the main results, either in one sentence or in multiple sentences. The latter was found to be the most usual form. The longest concluding statement (12 sentences; 10 numbered paragraphs) was found in a Pakistani RA, covering the entire conclusion section. While as many as eight Pakistani conclusion sections had such numbered paragraphs, no such instances were found in the native sample. The following examples serve to illustrate the first variation identified above. The accompanying titles and the research purposes are also included. In order to indicate the position of the extracts in their respective sections, the sentences are numbered. In addition, the Steps that are realised by a sentence, a group of sentences or a clause are provided in brackets. In the extracts from introduction sections, Step numbers are from the *CARS* model, while those from the discussion sections are from the model proposed earlier in this chapter.

---

(18) Title: Petrography and geochemistry of the inclusions from the Ambela Granitic complex, N. Pakistan [PAK-14]

Introduction:

[2.1b][3]An important component of the complex so far undescribed, however, is the inclusions of intermediate to felsic compositions which are contained in both the granites and syenites. **[3.1b]**[4]In this paper, we present petrographic data and whole-rock geochemistry for a representative set of samples from these inclusions. [5]An attempt is made to decipher their origin by comparing their trace element composition with their host rocks from the AGC, and country rocks in the surroundings.

Discussion:

[3.1][16]These features of the incompatible trace elements of the inclusions are closely comparable with the patterns of the volcanic rocks, suggesting that these inclusions were derived from the acidic volcanic phases of the region which partly made country rocks to the AGC.

(19a) **Title:** Calculated frequencies of the O-H stretching for different local orderings of Fe and Mg in simple clinoamphiboles [NS-08]

Introduction:

[2.1b][6]Whereas the short-range potential seems to transfer reasonably well to other clinoamphiboles, Abbott (1990, 1991) acknowledged that the transferability to amphiboles containing both Fe and Mg is less straightforward.... **[3.1b]**[20]In this paper, we use Distance-Least-Squares (DLS) analysis to create realistic geometries for the M(1) and M(3) polyhedra in simple clinoamphiboles containing Fe and Mg.... [23]By reproducing reasonable frequencies for the A, B, C and D bands, one goal is to learn more about local deviations from the average structures of simple Fe-Mg clinoamphiboles.

Discussion:

[3.1][39]By all indications, the differences in the frequencies of the A, B, C and D bands are specifically related to local variations in the structure [of simple Fe-Mg clinoamphiboles], especially with regard to the position of the hydroxyl oxygen, O(3). [40]The single most important factor influencing the position of the O(3) oxygen appears to be the ionic radius of the M(1) and M(3) cations.

(19b) **Title:** Heavy mineral analysis of the molasse sediments, Trans-Indus ranges, Kohat, Pakistan [PAK-02]

Introduction:

[4]With the availability of an adequate data on mineral chemistry from the Himalayan orogenic belt in N. Pakistan (R), **[3.1b]** it is now possible to compare the heavy

minerals in the molasse sediments from the foreland basin to exactly locate the source terrain for each stratigraphic level.

Discussion:

[3.1][19]Appearance of the amphibole at the base of the Shakardara Formation would record a metamorphic event responsible for the uplift and exposure of the upper to intermediate levels of the Kohistan arc crust. [20]The appearance of pyrobe-rich garnet in the uppermost molasse succession suggests exposure of the basal arc crust in Kohistan much later than the shallow to intermediate crustal levels.

Some conclusions were clearly signalled with an orienting structure, such as *We conclude*. However, in most discussions, the conclusion was signalled by reference to the preceding discussion, interpretation, experiments, reported results, examples, or to the study, or investigation:

1. From the above discussion, it is clear ... [PAK-03]
2. Therefore, in the light of our experiments ... [NS-03]
3. These results show that ... [NS-19]
4. However, from textural evidence we interpret that ... [NS-24]
5. The examples given above have served to ... [NS-18]
6. Our present study reveals that ... [PAK-16]
7. This investigation confirms that ... [NS-26]

In addition to the usual orienting structures (*We conclude that ...; In conclusion ...; Following conclusions ...; Thus ...*), one native discussion [NS-08] had a rare orientation, *By all indications ...* On the whole, eleven native discussions had such orientations while only six Pakistani discussions had such orientations.

As pointed out earlier, the writers answered their research questions in two different ways: as a concluding statement comprising a single sentence or a number of sentences, or as an ongoing process, spreading the answers throughout the discussion. Moreover, the former may be either explicit if preceded with an orienting theme, or implicit if not. Table 14 (see below) reports the results of this comparison.

As can be seen from Table 14, only three native discussions did not provide explicit answers to the research question(s), whereas eight Pakistani discussions did not answer the questions explicitly. In both cases, the reasons for not explicitly providing answers seem to be either dealing with a number of questions at the same time or failing to recognise and foreground the salience of a particular purpose in the introduction. Although no researcher failed to state the purpose of the study, the purpose sometimes seemed too broad to receive adequate discussion. For example, in the following introduction, the researcher specifies a very broad purpose:

TABLE 14: Aim types in Introductions & Conclusion types in Discussions.

SAMPLES	INTRODUCTIONS						DISCUSSIONS					
	Rqs		Probem		Purpose		Type 1a		Type 1b		Type 2	
	Expl	*Impl*	*Expl*	*Impl*	*Expl*	*Impl*	*Expl*	*Impl*	*Expl*	*Impl*	*Expl*	*Impl*
NATIVE	1	--	14	--	15	--	--	--	24	--	3	3
PAKISTANI	--	--	4	2	24	--	3	--	18	4	1	4

Notes:

RQs = Research Questions; *Type 1a* = One sentence conclusion;
Type 1b = More than one sentence conclusion; *Type 2* = Answers spread out; no conclusion;
Expl = Explicit; *Impl* = Implicit

(20) [9]This paper presents a detailed account of the petrography and geochemistry of the three major rock types, i.e., syenites, quartz-syenites and granites from the Babaji area of the complex. [PAK-30]

It is, therefore, difficult to judge whether the purpose is achieved. At least, it is not evident from the discussion section. An examination of the above example reveals that the chances of the discussion section having a conclusion are remote anyway, as the statement of purpose does not have any underlying question to bind the strands together. The title, “Petrochemistry of the rocks from Babaji area, a part of the Ambela Granitic complex, Buner, Northern Pakistan” does not provide the missing binding theme either. The discussion section consists of only thirteen sentences, almost all dealing with geologic processes. A research question for the following conclusion/deduction could have served to bind the seemingly unrelated strands:

(21) [9]The geochemical parameters of the Babaji rocks suggest that they may represent a typical extensional or release-type of plutonic suite, associated with rifting. [PAK-30]

There were other RAs, both native and Pakistani, with similar titles and purposes, but they were found to have an explicit conclusion, mainly because of an underlying binding question:

(22a) **Title:** Petrology and the grain size characters of the Pab Sandstone of parts of the Loralai and Khuzdar districts of Baluchistan

Introduction (purposes):

[8]The present paper is intended to describe the petrology and grain size parameters of the Pab Sandstone and an attempt has been made *to interpret the provenance and depositional environments* based on petrology and grain size parameters. [PAK-10]

(22b) **Title:** Sulphide mylonites from the Renstrom VMS Deposit, Northern Sweden.

Introduction:

[4]Most volcanogenic massive sulphide (VMS) deposits now exposed on land have been subjected to some degree of metasomatism and deformation, but despite this, ***many deformation textures in the sulphides are either not recognised or not reported, and may have been misinterpreted as primary textures***. [NS-23]

These two RAs, and several others, benefit from the fact that their statements of purposes or problems have an underlying purpose. It can, therefore, be argued that if an RA has an underlying primary research question to answer (question-oriented), or a primary problem to deal with (problem-oriented), it will be better directed and will ultimately have an explicit research conclusion.

As already reported, twelve native and fourteen Pakistani RAs had an additional conclusion section which listed answers to the main questions. The answers were found as a concluding statement in eleven native and eleven Pakistani conclusion sections. Usually, the entire conclusion comprised the answers.

As already discussed, all NSE introductions had a Move 2, but as many as eight Pakistani introductions did not have one at all and three had it embedded in Move 3; hence, no research questions or hypotheses were identifiable in these introductions to provide clues for the identification of the macroproposition in the their discussion sections. As all of these introductions had a kind of statement of purposes expressed as Move 3.1 or 3.2, the macroproposition was identified by referring to such expression of purposes. The statement of purpose was sometimes very vague and undirected (as illustrated in Example 20 above). In such cases, it was difficult to pin-point the main purpose for which a macroproposition could be established in the discussion. The title, then, seemed to offer a way out as the RA titles usually refer to the salient purpose or question that informs the study. But several Pakistani RA titles did not include such a clue either.

5.3 Summary and Conclusion

This chapter looked into the conceptual organisation of the discussion section, and attempted to answer two questions: a) whether the geology RA discussion section has a rhetorical structure as suggested for other disciplines, and if yes, whether it can be evolved into a model; b) whether the NSE and the Pakistani discussion sections differ in their rhetorical organisation or distribution of moves.

The division of the discussion section into three broad Moves revealed that the geology RA discussions do have a rhetorical structure. A comparison of the three Moves highlighted the Pakistani researchers' tendency to underplay the importance of presenting and discussing their findings clearly, logically and adequately. They were found to spend more time on presenting background information — much of which might be unnecessary — than concentrating on their findings, an oversight which may result in the research paper being rejected by an international journal, as found by Gosden (1992). Not discussing the results clearly and adequately appears to be a problem with a considerable number of NNS scientist writers. Twenty-eight percent of Gosden's (1992:132) respondents (journal editors) commented that, on the whole, failing to present and discuss their findings clearly and logically was the main problem for NNS researchers. Pakistani researchers appear to have the same problem. The quantitative comparison in terms of the presence or absence (or explicitness/ implicitness) of a main conclusion revealed that several Pakistani discussions did not have a clear research outcome. This has clear implications for such RA manuscripts being sent for international publication. It will be seen in Chapter 8 in the light of native referees' comments on Pakistani manuscripts whether they also see these tendencies as problematic. In order to overcome this widespread problem, Gosden suggests that the discussion section should be more thoroughly analysed for rhetorical structure, and conceptual organisation. The model for the RA discussion section proposed in this chapter appears to be very useful for both analytical and teaching purposes. However, in its linear form it does not capture the cyclic nature of the discussion section. An alternative form of this model (flowchart) for teaching purposes only is presented in Chapter 9, pedagogical implications. It will be shown that the flowchart model can easily overcome the problems identified in this chapter.◆

CHAPTER 6

Theme Choice & Method of Development

6.0 Introduction

In the last two chapters, we were concerned with the generic and rhetorical structuring of two research article sections: introduction and discussion. This chapter is concerned with the organisation of the RA discussion section as message: the textual meaning. Accordingly, RA discussions from the two datasets are compared for patterns of theme choice; that is, what theme choices, unmarked and marked, the native and the Pakistani writers make to organise the message, and what meanings — textual, interpersonal, experiential — they typically foreground in their texts. As thematic choices have implications for textual structuring, it is also the purpose of this chapter to analyse the two categories of texts for method of development. As pointed out in Chapter 3 (3.3.3), the process of making meaning is based on paradigmatic relations within a system network. With regard to this, a distinction has already been made between what one *can* mean (***potential*** meaning) and what one *does* mean (***actual*** meaning) at a particular point in a system network. A text may be seen as a record of what the writer did actually mean which can, then, be described and explained with reference to the choices available in system networks. It should be remembered that the writer has the choice to frequently use, to occasionally use, or not to use at all a certain theme. These choices give rise to thematic variation in texts. And if the texts under study belong to a single genre, thematic variation will evince the type and the background of the writers: experienced/inexperienced, and native/non-native.

6.1 Theme Choice: Patterns and System

The system network of theme choice, as discussed in Chapter 3 (Section 3.3.4), is reproduced below as Figure 12.

```
                      ┌─ 1) Subject (declarative)     ⎫ M
                      ├─ 2) Wh-     (Interrogative)   ⎪ O
        ┌─ UNMARKED ──┼─ 3) Finite  (Interrogative)   ⎪ O
        │             └─ 4) Process (Imperative)      ⎭ D
        │
        │             ┌─ 1) Prep. Phrase as Theme
        ├─ Marked ────┤
        │             └─ 2) Complement as Theme
THEME ──┤
        │             ┌─ 1) Interpersonal (Modal Adjuncts)
        ├─ Multiple ──┤
        │             │              ┌─ Structural Theme (Conjunctions/Relatives)
        │             └─ 2) Textual ─┤
        │                            └─ Discourse Theme (Conjunctive Adjuncts)
        │
        │             ┌─ 1) Predicated  (clefts, pseudo-clefts)
        └─ POSTPONED ─┼─ 2) Anticipated (extraposition)
                      └─ 3) Existential (presentative, there)
```

Figure 12: System Network of Theme Choice

As can be seen, the system network of theme offers the writer (and the speaker) three choices: those of unmarked, marked, and postponed themes. Put simply, when theme conflates with that constituent of the Mood structure which typically occurs in clause initial position, the result is unmarked theme. However, when theme conflates with any other constituent from the Mood system, we get marked theme. Typically, all things being equal, the writer will choose the unmarked theme. The choice of a marked theme, therefore, tells the reader that the writer has some special purpose — textual, rhetorical, pragmatic — in making the atypical choice: "marked Theme usually either express some kind of setting for the clause or express a feature of contrast" (Halliday, 1994:48). Experienced writers choose marked themes to add coherence and emphasis to their texts. Generally, two sequential clauses (simplex or complex) in a text contain something common that links them.[1] The second clause follows up, adds to, or builds on whatever is the main point of the preceding clause. The main point, according to Fries (1981), is the 'new' information which typically

---

[1] Schegloff and Sacks (1973/74:296) call this property of the language ***sequential implicativeness*** by which they mean that each utterance or clause creates a context for the following utterance or clause.

falls within the rheme. The writer must, therefore, employ special means to apprise the reader of any change in the development of the text; that is, in situations when the clause about to be executed does not directly grow out of the preceding clause. Such changes and shifts are usually indicated by marked themes.

On the basis of the discussion in Chapter 3 (3.3.4), I argue that the difference between 'what the clause is about' and what 'the point of departure of the clause is' needs to be accounted for in clearer terms if we are to exploit the potential that this Hallidayan distinction offers us. In multiple themes — when 'what the clause is about' is different from what 'the point of departure of the clause' is — it would be useful to refer to the initial element as simply 'the point of departure' rather than theme. This distinction is important for our present purposes as we are concerned with what atypical choices the two categories of writers usually made. The following two examples serve to illustrate this distinction:

(1)

The Polyhedron	can adjust its configuration to adapt to the small cation movement of the cation ...
Topical	
THEME	**RHEME**

(2)

However,	large bodies of hornblende-rich gabbros and diorites	occur elsewhere in the world.
Point of Departure	Topical (what the clause is about)	
THEME		**RHEME**

As can be seen, the theme in Example (1) is represented by one element which is the topic (grammatical subject) of the clause whereas in Example (2), the theme consists of two elements: a point of departure and a topic. Without the point of departure, it would be difficult to establish an appropriate interpretive context for the ensuing clause. As such, points of departure provide explicit linear contexts of *sequential implicativeness* (Schegloff and Sacks, 1973/74) for the topic or topical theme of the clause. Such points of departure play a very crucial role in those points in the text where there are breaks in thematic continuity, e.g., when there is a total change of topic (Lemke, 1988:168). Halliday's (1994:84) point of note that conjunctive adjuncts construct a context for the clause can be extended to include other points of departure — interpersonal, textual, and clause initial adjuncts (excluding circumstantial)[2] — as they all serve the same purpose. The following examples serve to illustrate this extension:

(3)

Unfortunately,	such ambiguity	is difficult to eliminate completely in comparing halides and ... ligands.
Point of Departure	Topical	
THEME		**RHEME**

(4)

In general,	the garnets	are between 5 and 15mm in diameter, red or red-brown, euhedral and contain many ...
Point of Departure	Topical	
THEME		**RHEME**

(5)

To some extent,	the large number of trace elements ...	poses questions that would be unlikely to arise in natural silicate minerals ...
Point of Departure	Topical	
THEME		**RHEME**

It is also possible to extend this implication to postponed themes (predicated, and anticipated) as the *it*-clauses in such constructions serve as points of departure for the themes that occur later in the clause. The following examples illustrate this implication:

---

[2] As circumstantial adjuncts can be assigned Transitivity roles, they function as topical themes in clause initial positions. According to the principle of Multiple theme, whatever follows the topical theme element is assigned to the rheme. If an adjunct cannot be assigned a Transitivity role, it will function as the point of departure of the clause alone. Such adjuncts are followed by topical elements. Compare Examples 4, 5 and 8 below.

(6)

It is however,	kinetic factors and not thermodynamic stability that	ensure long-term preservation of the marcasite structure ...
Point of Departure	Topical	
THEME		**RHEME**

(7)

It is suggested that	exsolution of an aqueous phase from the melt	complexed available Mn and transported it
Point of Departure	Topical	
THEME		**RHEME**

In each of these examples, the point of departure comprises the entire projected clause. Mostly, such projected clauses are interpersonal (when interpreted metaphorically) and, therefore, Example (7) can take the form 'I/We suggest that' as in Example (8) below:

(8)

We suggest that	the large resorbed plagioclase samples	represent partial crystallization of the magma at depth.
Point of Departure	Topical	
THEME		**RHEME**

In this study, all those projected clauses which contain an element of modality will be interpreted metaphorically, hence constituting interpersonal theme. Example (9) is one such example:

(9)

I believe that	it is because of the overall symmetry of the system and general lack of block rotation	that the restoration appears to be reasonable and successful.
Point of Departure	Topical	
THEME		**RHEME**

Projected clauses can be used to serve textual purposes as well. For example, *It follows that* means 'as a result' or 'consequently' and *It is noted above* means the same thing as *As noted above*. All such postponed themes are classified according to their functional meaning.

But an initial adjunct may also comprise the theme of the clause as a whole and not the point of departure alone; e.g., circumstantial adjuncts, because they can be assigned transitivity roles in the clause. Similarly, initial dependent clauses are also thematic as a whole and provide an interpretive framework for the following independent clause. The following examples illustrate these themes:

(10)

Of the two authigenic phases	the low-(Ce/La) ellipsoids appear to postdate the high-(Ce/La) veinlets.
THEME	**RHEME**

(11)

As the fluid lens is driven away from the site of initial hydraulic fracturing,	the bedding-plane slip ceases at this locality and the system locks up.
THEME	**RHEME**

6.2 Materials and Method

For the quantitative comparison of theme types, all the discussion sections in the two datasets were used. However, for illustrating the method of development, two paragraphs were selected from the Pakistani dataset. The decision to use only the discussion sections was based on the findings reported in the previous chapter. In the discussion section, the writer has to report findings, interpret them, and draw inferences and conclusions from them. This, as a consequence, requires a good deal of discourse management, topic shifting, and cross referencing. The discussion section is, therefore, a rich source of every type of theme with intricate information, and topic structure.

Thus, for quantitative comparison of theme choice across the two datasets, all instances of marked/multiple, and postponed themes were marked in all the discussions (30 each) at the clause level. (Lists of all theme types thus marked in the two datasets are provided in Appendix D-1 and D-2). Although a clause complex may contain any combination of themes, only the initial element (or point of departure) was considered for quantitative comparison, for it is the initial thematic element that is most important for text development, being the point of departure for the whole clause.

Once all theme types were counted in the sixty discussion sections and once they were classified as interpersonal, textual, clausal, etc. according to the classification proposed above, it became apparent that there were differences in the choice of theme . In order to test for significance, the following statistical design was adopted:

H_0: There are no differences in the NSE and the Pakistani geologists' choice of Theme as evidenced in their RA discussions.

H_1: There are differences in the NSE and the Pakistani geologists' choice of Theme as evidenced in their RA discussions.

Significance level? .... $p < 0.05$

Design

Dependent variable(s)? .... Theme choice
Measurement? .... Frequency Tally
Independent Variable(s)? ... ± Native Speaker of English
Measurement? .... Nominal, 2 levels
Independent or repeated? ..... Independent

Other features? .... Intact class
Statistical procedure? .... Chi-Squared Test (χ^2)

6.3 Quantitative Findings

Table 15 lists the number of occurrence (frequency) of each theme type and their percentage (expressed as a percentage of all themes) in thirty native and thirty Pakistani RA discussion sections. Percentages throughout are rounded to 0.01%.

As can be seen from Table 15, the unmarked theme, which is the usual choice, is the most abundant, occurring with approximately the same frequency in both the NSE (64.08%) and the Pakistani discussions (66.97%) followed by discourse themes. However, the native writers used more *structural* and *interpersonal* themes whereas their Pakistani counterparts used more *discourse* and *postponed themes*. A Chi-

Squared Test shows that these differences are significant ($\chi^2 = 11.29$, $df = 5$, $p < 0.01$).

TABLE 15: Frequencies (*f*) of theme types in the Native and the Pakistani discussions.

	NATIVE		PAKISTANI	
THEME TYPES	***f***	**%**	***f***	**%**
Unmarked	669	64.08	509	66.97
Marked	78	07.47	59	07.76
Interpersonal	52	04.98	25	03.29
Structural	76	07.28	35	04.61
Discourse	156	14.94	112	14.74
Postponed	13	01.25	20	02.63
	1044	100	760	100

($\chi^2 = 14.58$, $df = 5$, $p < 0.01$)

Table 16 lists the observed (O*f*) and the expected frequencies (E*f*) of all theme types. Comparing the observed and the expected frequencies for each theme type, we find that while the native geoscientists used fewer unmarked themes than expected, their Pakistani counterparts used more unmarked themes than expected. However, the differences are not significant statistically. For marked themes, too, the differences were found not significant.

Similarly, we can see that the Pakistani geoscientists used fewer interpersonal and structural themes than expected, whereas the native geologists used more of these themes than expected. As for discourse themes, the Pakistani geologists used more discourse themes than expected whereas the native geologists used fewer discourse themes than expected. However, the differences between the observed and the expected frequencies of only the *interpersonal* and the *structural* themes are significant at the 95% confidence level set for this study ($\chi^2 = 3.70$ with Yates Correction for the interpersonal, and $\chi^2 = 4.88$ with Yates Correction for the structural themes). Differences in the observed and the expected frequencies of the postponed themes were also statistically significant at the 95% confidence level ($\chi^2 =$ 4.69 with Yates Correction).

TABLE 16: Contingency table of Observed (Of) & Expected (Ef) frequencies of all Theme Types in Native and Pakistani RA discussions.

	Native		**Pakistani**		**Totals**
	O*f*	**E*f***	**O*f***	**E*f***	**O*f* + O*f***
Unmarked	669	682	509	496	1178
Marked	78	79	59	58	137
Interpersonal	52	41	25	30	71
Structural	76	64	35	47	111
Discourse	56	155	112	113	268
Postponed	13	23	20	16	39
TOTALS	**1044**		**760**		**1804**

($\chi^2 = 14.58$, $df = 5$, $p < 0.01$)

As differences are statistically significant mainly for the *interpersonal* and the *structural* themes, we can, therefore, conclude that the Pakistani geologists would generally use fewer interpersonal and structural themes than their native counterparts. We can also conclude that the Pakistani writers would use more postponed themes. The implications of the findings are discussed below.

6.4 Discussion

6.4.1 Thematic Choices

Thematic choices are important for maintaining proper focus and orientation. Theme as point of departure provides the reader with a contextual framework which helps him not only to interpret the ensuing stretch of discourse but also to create links with the preceding stretch of discourse. The text that evolves in this way has not only cohesion but also coherence.

As already pointed out above, theme as point of departure (as opposed to what the clause is about) is the atypical choice. This choice the writers make to maintain focus, to introduce a new (or reintroduce an old) topic with proper orientation and cohesion, or to express their personal view about, judgement of, or attitude towards their propositions and statements. Thematic choices, therefore, have rhetorical import, and clause-initial position, in particular, appears to be significant, since the choice of a marked theme enables the writer to foreground a particular 'writer-selected signal' (Gosden, 1992:208), to signal, for example, the onset of a rhetorical move (see Chapters 4 & 5).

The taxonomy that Halliday (1985, 1994) has presented for thematic choices, particularly the distinction between the interpersonal and the textual (discourse and structural), is useful in that it has the potential to be used to evaluate texts which, according to Halliday (1994:xv), is the higher level achievement. The interpersonal (modal adjuncts) and the discourse themes (conjunctive adjuncts), in this taxonomy, are typically thematic, whereas the structural themes (conjunctions & relatives) are obligatorily thematic (Halliday, 1994:48-49).

Significantly fewer (than expected) interpersonal themes in the Pakistani RA discussions indicate that they either avoided or did not feel the need to make their own angle the point of departure for their messages. However, it is hard to accept that a scientist can remain detached from what he is reporting. According to Davies (1988):

> writers are concerned not only with the content of what they are reporting, but are also necessarily committed to particular stances or points of view in respect of their own research and that of others.
>
> *[Davies, 1988:174]*

It appears that the Pakistani geologists are not aware of the importance of maintaining a balance between what Gosden (1993:56) terms "interactional 'human face' discourse and impersonal topic-based discourse". In other words, they seem to avoid "a high discourse profile" (Gosden, 1992:214).

We also note that the Pakistani geologists foregrounded or thematised significantly fewer structural elements in their discussions (conjunctions and relatives); however, their foregrounding of discourse adjuncts matched with the native geologists' thematising of such elements. As conjunctions and relatives set up mainly a structural (grammatical) relationship between clauses (Halliday & Hasan, 1976:6), it appears that the Pakistani discussions lack explicit cohesive signals. Nonetheless, the Pakistani discussions do not appear to lack coherence as the sparse use of explicit cohesion is compensated for by the abundant use of discourse adjuncts which "set up a semantic relationship with what precedes" (Halliday, 1994:50). However, as Gosden (1992:209) notes, the use of subordinating conjunctions, such as, *although*, is structurally more complex than the use of discourse adjuncts, such as *however*. Note the frequency of *although* in the native discussions (11 instances) and the Pakistani discussions (only 2 instances).

Although "discourse is not dependent on overt cohesion of this kind" (Widdowson, 1978:27)[3], "[w]riters and readers depend upon signals to convey and redeem meaning in texts" (Eiler, 1986:49). The writer is responsible to make overt by signalling to the reader the global as well as the local relations that obtain as the propositions unfold and the text evolves. The Pakistani writers appear to be paying attention to the global coherence of their texts, but seem to be ignoring local cohesion. As a corollary, and by implication, the Pakistani writers appear to be using more co-ordination than subordination to develop their thoughts and ideas, which, according to Hunt (1965) indicates less syntactic maturity. An example of excessive co-ordination is given below:

(12) The normal granite gneiss of Jolagram and Jalal Kot *corresponds to Malakand granite* on the basis of their chemistry, <u>and</u> considered [*sic*] to be of igneous parentage <u>and</u> are *generally related to the Malakand granite*. [PAK-22]

Ignoring for the time being the clumsiness of the sentence,[4] we see that it has two occurrences of the co-ordinating conjunction, *and*, which could have been avoided. In fact, the idea expressed after the second *and* (*generally related to the Malakand granite*) is a repetition of what has already been stated (*corresponds to Malakand*

[3] Brown and Yule (1983:194ff) hold the same view. For them, a text is coherent not by virtue of textual cohesion alone which is neither a necessary nor a sufficient condition of discourse coherence, but by virtue of the extra-linguistic context in which it was produced.

[4] The clumsiness of this sentence and of other such sentences will be discussed in the next chapter in section 7.4.

granite). In this case, lack of appropriate structural cohesion not only confuses the proposition, but also indicates that the writer himself was not clear how to express and structure the proposition.

Another statistically significant difference was found in the use of ***postponed themes*** which includes *predicated themes* (clefts, pseudo-clefts), *anticipated themes* (extraposition), and *existential* themes (presentative, *there*). We found that the Pakistani geologists used postponed themes not only more than expected but also more than their native counterparts. However, in order to interpret this particular finding, we need to anticipate the discussion in Chapter 7 where we will be discussing the use of First Person pronouns.

According to the findings reported and discussed in Chapter 7, the Pakistani geologists used fewer projected clauses of the personal kind, *We suggest/propose*, than the impersonal, *It is suggested/proposed*. This tendency has increased the relative proportion of postponed themes in the Pakistani discussions. In fact, we find that the Pakistani geologists have used twice as many projected clauses of the impersonal type than the native geologists.[5] There is even an odd sounding construction with *There*, an extreme case of impersonalising (*There are strong reasons to think*). If the reasons are strong, why not write *We have strong reasons to believe*? But this is a moot question.

On the basis of the foregoing discussion, we can conclude that the Pakistani RA discussions will be less effective in terms of achieving the purpose for which they are written, particularly, in the international scientific arena. These papers may be rejected by international native editors and referees if the science reported is also of low merit. These papers have exactly the problems that have been pointed out by Gosden's (1992) respondents. Gosden asked international journal editors to rate the degree of *influence* of ten aspects on their judgement when they consider NNS manuscripts for

---

[5] It needs to be pointed out that these figures do not include the number of similar projected clauses with fronted textual themes; e.g., *However, it is suggested/ proposed*, etc.

publication. In view of our present concerns, let us look at the rank order of the first five aspects:

1. logical and clear linking of sentences for the reader.
2. development of the topic from sentence to sentence in a coherent way.
3. use of grammatically correct sentences.
4. ability to manipulate skilfully the language in making this [sic] claim.
5. appreciation of the level of claim that can justifiably be made for their research.

[Gosden, 1992:126]

According to our findings, the Pakistani geologists did not use enough structural cohesive signals to link sentences; however, their RA discussion sections, on the whole, appear to have coherence as they used enough discourse themes. (More will be said on these two aspects, logical linking & coherence, in the next section, method of development.) As for aspect 3, not very many grammatical errors were found in the Pakistani discussions, apart from a few sentence fragments and unbalanced lists. It was not unexpected, given that the dataset consisted of published research papers. Anyway, this study was not concerned with grammar as such, but with the making of meaning, and the choices that the two categories of writers made to instantiate meanings. The last two points — in fact, I would put these two aspects at the top of the list — are concerned with the rhetoric of making claims. This involves weighing the status of one's evidence and the extent to which one is prepared to commit oneself to the truth value of one's claim, and deciding whether to make a subjective or an objective assertion. Fewer interpersonal and very many postponed themes in the Pakistani discussions suggest that the Pakistani geologists may not be asserting their claims properly. According to Basham and Kwachka (1991:39): "Overstatement of a case leaves the writer open to criticism and refutation, whereas an understated argument may go unnoticed."

In short, what the editors of international journals perceive as important for international publication, the Pakistani geologists do not pay heed to. It is, therefore, of utmost importance that they be made aware of these inadequacies in their scientific reporting. Chapter 9 is concerned with the question of raising this awareness among the Pakistani geologists in particular, and other Pakistani scientists in general.

6.4.2 Method of Development

Let me begin this section with an important quote from Halliday (1985):

> by analysing the thematic structure of a text clause by clause, we can gain an insight into its texture and understand how the writer made clear to us his underlying concerns.
>
> *[Halliday, 1985:67]*

The choice of unmarked, marked, multiple, and postponed themes creates a pattern that contributes to the cohesion and coherence of texts. However, it is the chaining of experiential themes (also known as topical themes) which determines the flow of the topic under discussion. This chaining of experiential themes is known as the *method of development* (Fries, 1981). The method of development of a text, according to Fries (1981), can be illustrated by looking at the experiential (topical) themes in clauses. In this section, I attempt to illustrate the method of development of Pakistani texts by analysing two paragraphs from two Pakistani discussion sections (PAK-03, PAK-14). The decision to use only paragraphs, and not complete discussion sections, was based on the understanding that themes primarily operate locally at paragraph level. These two paragraphs were randomly selected. First, thirty paragraphs, one each from the thirty discussion sections, were drawn; second, two paragraphs were drawn at random from those thirty paragraphs. Very long and very short paragraphs were ignored in the selection process. The two passages are discussed in detail with suggestions for revision. Numbers in square brackets represent running sentence numbers in the discussion sections from which the examples are taken:

PAK-03 Paragraph #5

[19] From the above discussion, it is clear that ***the Patala Formation in Kohat area generally*** exhibits fining upward sequence. **[20]** ***This fining upward trend*** is most probably related to the continuous deepening environments of deposition during sea transgression. **[21]** ***Rashid et al., () mistakenly*** considered the overturned strata of the Patala Formation at Kohat Pass as a normal sequence. **[22a]** Consequently, ***strata of the basal facies PF1*** makes top of their lithologic column, **[22b]** and ***uppermost facies PF4 in this article [?]*** makes their basal strata. **[23]** Based on their lithologic column, ***Rashid et al., ()*** had suggested a prograding upward sequence for the Patala Formation. **[24]** In reality, ***the sequence*** is transgressive upward.

This passage consists of six sentences (seven clauses). The first clause of the passage [19] has a complex three part theme: ***Textual^Interpersonal^Topical***. The textual theme marks not only the point of departure for the passage as a whole, but also establishes a discourse link with the preceding four paragraphs. While the writer, by thematising the textual theme (*From the above discussion*), tells the reader that what follows is an interpretation of the entire foregoing discussion, he, at the same time, tells the reader, by including the interpersonal theme (*it is clear*), that the foregoing discussion provides clear evidence for the succeeding conclusion. However, the writer cautiously modalizes his claim by interposing a modal adverb, *generally* between the topical theme and the verb.

The second clause [20] has the topical theme in the subject initial position which is derived from the preceding rheme. The use of anaphoric deictic, *This*, is not only emphatic (only this *fining upward trend* and no other), but also establishes grammatical cohesion on top of the lexical cohesion which is already there. Note again the use of modal adverb in the rheme.

TABLE 17: Method of development of Paragraph #5 (PAK-03).

	THEME:		**RHEME:**
	Non-Topical Themes *(Textual & Interpersonal)*	Topical Themes *(method of development)*	*(New, the main point)*
[19]	From the above discussion, it is clear that	the Patala Formation	fining upward sequence
[20]		This fining upward trend	deposition during transgression
[21]		Rashid et al., ()	i) overturned strata of Patala Formation (ii) normal sequence
[22] a) b)	Consequently, and	strata of the basal facies PF1 uppermost facies PF4	top of their lithologic column their basal strata
[23]	Based on their lithologic column,	Rashid et al., ()	i) prograding upward sequence (ii) Patala Formation
[24]	In reality,	the sequence	transgressive upward.

The next clause [21] also has a topical theme, *Rashid at al.*, in the subject initial position which, though not derivable from the preceding five paragraphs, does not pose much problem in view of the fact that it is a scientific report. However, careful writers might still prefer to use a textual or even an interpersonal point of departure to situate the new topic. This clause could be recast as follows:

To depict the process, Rashid et al., () have proposed a lithologic column which misinterprets the overturned strata of the Patala Formation at Kohat Pass as an instance of normal sequence.

Clause [22] has a textual (discourse) theme as its point of departure which sets up a consequential relation between the immediately ensuing clause [22a] and the preceding one. This clause is followed up by a coordinated clause [22b] with the co-ordinating conjunction, *and*. The context reveals that the writer intended the consequential relation to hold for clause [22b] as well, but to carry through this relation forward, the writer needed a subordinating conjunction, such as *whereas*, immediately after the discourse adjunct (or in place of *and*). In addition, there appears to be a break in the continuity of topical theme. The topical theme, *[the] strata of the basal facies PF1*, discussed in the second paragraph and briefly mentioned in the third paragraph, is not immediately derivable. Making the rhemes of clauses [22a] and [22b] — *[the] top of their lithologic column* and *their basal strata* — the themes of their respective clauses would engender continuity with the topic of clause [21], *Rashid et al.*, which is the referent of the two occurrences of the pronoun, *their*. The clause could, then, be rewritten as follows:

Consequently, whereas the top of their lithologic column corresponds to the strata of the basal facies PF1, their basal strata correspond to the uppermost facies PF4.

Clause [23] again has a discourse theme which refers back to the rheme of clause [22a] and provides an interpretive context for the ensuing clause. Similarly, the final clause [24] of the paragraph also has its point of departure a discourse adjunct, *In reality*, which lends to the refuting claim a kind of conclusiveness.

Looking at Table 17, we find that the method of development of the paragraph becomes disjointed for a while after clause [20]. The topical themes are not properly chained, and the textual points of departure which precede the topical themes do not create satisfactory links. On the other hand, the method of development of the modified version (Table 18), gives a better look in terms of chained topical themes.

TABLE 18: Method of development of Paragraph #5 (PAK-03) after modification.

	THEME:		**RHEME:**
	Non-Topical Themes *(Textual & Interpersonal)*	Topical Themes *(method of development)*	*(New, the main point)*
[19]	From the above discussion, it is clear that	the Patala Formation	fining upward sequence
[20]		This fining upward trend	deposition during transgression
[21]	To depict the process,	Rashid et al., ()	i) a lithologic column (ii) overturned strata as normal sequence
[22]	Consequently, and	a) top of their lithologic column b) their basal strata	i) strata of the basal PF1 ii) the uppermost facies PF4
[23]	Based on their lithologic column,	Rashid et al., ()	i) prograding upward sequence (ii) Patala Formation
[24]	In reality,	the sequence	transgressive upward.

Now let us look at the second example which is from PAK-14. This is the fourth and final paragraph of the section.

PAK-14 Paragraph #4

[11] In Figure 1, *mantle-normalised trace elements pattern of the inclusions* are compared with those of the Ambela granites, syenites and volcanic rocks. **[12]** As far as *the general concentration* is concerned, *the inclusions* are not substantially different from all the three lithologies represented for comparison. **[13]** *Both the Ambela granites and syenites* are characterised by a general negative Nb anomaly which is particularly pronounced in one of the latter. **[14]** Also *the Rb-Ce segment of the pattern in granites and syenites* is generally significantly spiked. **[15]** In comparison, *the trace element patterns of the inclusions* are characterised by a flat Rb-Ce segment and a positive Nb anomaly. **[16]** *These features of the incompatible trace elements of the inclusions* are closely comparable with the patterns of the volcanic rocks, suggesting that *these inclusions* were derived from the acidic volcanic phases of the region which partly made country rocks to the AGC [Ambela Granitic Complex].

Looking at Table 19, we see that, although the paragraph has a consistent focus in terms of what is being discussed, there are a few problems with its method of development. Let us first look at the paragraph clause by clause.

The first clause [11] begins with a discourse theme, *In Figure 1*, which is the basis of the comparison around which this paragraph is built. The first clause introduces the four entities which are being compared for their *trace element patterns*: the inclusions, the Ambela granites, syenites, and volcanic rocks. First, they are compared for the general concentration of trace element patterns (Clause [12]). Second, two of the four lithologies, the Ambela granites and the syenites are compared for *Nb anomaly*

(Clause [13]). The two entities are again compared for *Rb-Ce segment* (Clause [14] which has a discourse theme, *Also*). Next, the Ambela granites and the syenites are compared (rather contrasted) with the inclusions on these two characteristics (Clause [15]; note the discourse theme, *In comparison*). Finally, the last entity, volcanic rocks, are shown to be comparable with the inclusions on these accounts.

TABLE 19: Method of development of Paragraph #4 (PAK-14).

	THEME:		**RHEME:**
	Non-Topical Themes *(Textual & Interpersonal)*	Topical Themes *(method of development)*	*(New, the main point)*
[11]	In Figure 1,	mantle normalized trace element pattern of the inclusions	[mantle-normalized trace element patterns] of i) the Ambela granites ii) syenites iii) volcanic rocks
[12]	As far as the general concentration is concerned	the inclusions	not substantially different from all the three lithologies
[13]		Both the Ambela granites and syenites	i) general negative Nb anomaly (ii) pronounced in the latter
[14]	Also	the Rb-Ce segment of the pattern in granites and syenites	generally significantly spiked
[15]	In comparison,	the trace element patterns of the inclusions	i) flat Rb-Ce segment ii) a positive Nb anomaly
[16] a)		These features	patterns of volcanic rocks
b)	suggesting that	these inclusions	the acidic volcanic phases of the region

There is one major problem with the method of development of this paragraph. Clause [13] and clause [14] are not parallel in terms of textual configuration. Although the two clauses are about the same two entities, clause [13] has the two entities in thematic position whereas clause [14] has a characteristic of the two in thematic position. As such, clause [14] could be rewritten as follows:

Further, their trace element patterns are characterised by significantly spiked Rb-Ce segment.

Better still, clauses [13], [14], & [15] could be rewritten as one clause complex [13]:

[13] However, whereas the trace element patterns of the Ambela granites and the syenites are characterised by a general negative Nb anomaly (particularly pronounced in the latter) and significantly spiked Rb-Ce segment, those of the inclusions are characterised by a positive Nb anomaly and a flat Rb-Ce segment.

The adversative, *However*, was needed to set up a proper logical relation between the clause complex and the preceding clause [12]. Note that whereas clause [12] is about the general concentration of trace element patterns in the four entities on which account they are found to be not substantially different, the rewritten clause complex [13] compares three of the four entities on specific features on which account they are found to be different.

Looking at the method of development of the paragraph after revision (Table 20 below), we find that the topical themes are properly chained with a consistent focus throughout on the features of the entities.

TABLE 20: Method of development of Paragraph #4 (PAK-14) after revision.

	THEME:		**RHEME:**
	Non-Topical Themes *(Textual & Interpersonal)*	Topical Themes *(method of development)*	*(New, the main point)*
[11]	In Figure 1,	mantle normalized trace element pattern of the inclusions	[mantle-normalized trace element patterns] of i) the Ambela granites ii) syenites iii) volcanic rocks
[12]	As far as the general concentration is concerned	[general concentration of] the inclusions	not substantially different from all the three lithologies
[13]	However, whereas	a) the trace element patterns of Ambela granites & syenites b) those [trace element patterns] of the inclusions	i) general negative Nb anomaly ii) a significantly spiked Rb-Ce segment i) a positive Nb anomaly ii) a flat Rb-Ce segment
[14] a)		These features [Nb anomaly and Rb-Ce segment]	closely compatible with the patterns of volcanic rocks
b)	suggesting that	these inclusions	the acidic volcanic phases of the region

The foregoing brief discussion reveals that the Pakistani geologists might have problems with developing their topics. Although the two paragraphs just looked at do not appear to be incoherent altogether, they do not possess what might be termed *properly chained topical themes*. The chaining of topical themes is important for a consistent focus on the topic of discussion. If there are too many breaks in the chain, the reader might loose the thread of discussion. The fact that we have been able to find problems with such short paragraphs leads us to believe that there might be, *a fortiori*, many more such problems in longer paragraphs.

6.5 Summary and Conclusion

This chapter was concerned with theme choice and the method of development of topical themes in Pakistani and native RA discussion sections. Theme choice (as point of departure) is important in that it shows the writer's textual and interpersonal concerns clause by clause. Theme choice not only helps the writer to introduce new topics, establish cohesion and coherence, it also allows him to show his attitude, opinion, commitment, and evaluative judgement. Similarly, the method of development shows the writer's ideational concerns clause by clause. A taxonomy of theme types was proposed which then served as the basis of comparison for the study. A comparison of the Pakistani and native RA discussion sections revealed that the Pakistani geologists used fewer interpersonal and fewer textual (structural) themes. We can, therefore, reject the null hypothesis of no difference. In addition, an analysis of two paragraphs from the Pakistani discussion sections revealed that the Pakistani geologists might have problems with chaining topical themes to develop a consistent focus on the topic under discussion.

In view of the fact that the dataset consisted of published RAs, it is not difficult to imagine the extent of such deficiencies and errors in manuscripts submitted to international journals. Because such errors may sometimes make a sentence outright incomprehensible as well as irritating, it is not difficult to visualise what the response of the native referees could be. Only if the science is of very high quality that the referees may be inclined to recommend a manuscript for publication, often on the condition that the authors do extensive rewriting. And if the problems are not accurately pointed out (as they are often not), they may persist in subsequent revised submissions.

The issue of acceptance of manuscripts by international journals will be explored in Chapter 8. An attempt will also be made to look for similar errors and whether the referees were able to point them out to the authors. Implications of these findings for pedagogical purposes will be taken up in Chapter 9.◆

CHAPTER 7

Rhetorical Prosodies

7.0 Introduction

In Chapter 6, we looked at the clause in its function as a message. But the clause also functions as an exchange between the writer and the reader, hence constituting an event (Halliday, 1985:68). In the systemic-functional approach, the interaction between the writer and the reader is designated as the interpersonal function which is linked to one of the three variables that define register and genre, namely, the ***tenor of discourse***. Tenor has been used to classify discourse. For example, Huddleston, Hudson, Winter, and Henrici (1968) successfully demonstrated the role of tenor as a contextual variable in realising text structures. On the basis of tenor -- participant relationships between writers and readers of texts — they classified scientific texts as either highly specialised, moderately specialised, or popular level. Adams-Smith (1984) found 295 examples of author's comments (interpersonal rhetoric) in 1091 lines of her six medical RAs with "a high proportion of epistemic expressions and a significant number of recommendations and expression of obligation with *should* and *must*" (p. 30).

Rhetoric, as used and understood in this study, is effective argumentation (see section 2.1.5 above). Academic discourse is essentially argumentative; hence, it cannot fulfil its primary social purpose of contributing to the pool of scientific inquiry without the use of rhetoric. Rhetoric, as such, is the *raison d'être* of scientific inquiry because the reporting scientist has not only to argue for his claims but also to save his face. Rhetorical prosodies help the scientist-reporter to co-ordinate these otherwise irreconcilable purposes. It appears to be quite a task for the non-native writer as he has to attend to three issues at the same time: the language, the argument, and his own face, both positive and negative (Brown & Levinson, 1987). Such being the case, non-native scientific discourse may be different from native discourse in one or several ways.

In the case of the Pakistani geologists, we saw in Chapter 6 that they used fewer interpersonal and textual themes. Based on this, we can hypothesise that the Pakistani geoscientists will use fewer rhetorical prosodies than their NSE counterparts.

7.1. Materials and Method

The frequency with which the writers use rhetorical prosodies in their writings affects the degree of the interactiveness of the texts they produce with respect to their readers. This frequency can be measured to compare whether text are more or less interactive and to distinguish different text types (Smith, Jr. 1985:243). As a corollary, such frequency counts can be used to compare texts of the same genre written by NSE and NNSE. As the purpose of this study was to compare the NSE and the Pakistani RAs on this account, it was important to use RA sections that had a good deal of rhetorical prosodies as defined and classified in Chapter 3 (section 3.3.5). In the light of the results reported by Butler (1990) and Adams-Smith (1984) that the discussion sections contain the most modal expressions and the most authorial comments, we decided to use only the discussion sections for the analyses. In total, thirty native and thirty Pakistani RA discussion sections were analysed.

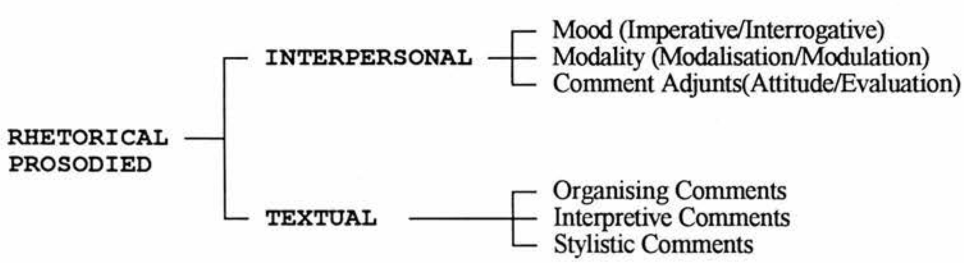

Figure 13: A classification of rhetorical prosodies.

All instances of rhetorical prosodies were marked, classified, counted and tabulated in accordance with the taxonomy outlined in Chapter 3 and summarised in Figure 13 above. Lists of all rhetorical prosodies found in the two datasets and classified according to the given framework are provided in Appendix D-3 and D-4.

As this study is concerned with counting frequencies, the following research design was adopted for significance testing.

H_0: There are no differences in the NSE and the Pakistani geologists' use of *rhetorical prosodies* as defined in this study and as evidenced in their RA discussions.

H_1: There are differences in the NSE and the Pakistani geologists' use of *rhetorical prosodies* as defined in this study and as evidenced in their RA discussion.

	Significance level?	$p < 0.05$
Design		
	Dependent variable(s)?	Rhetorical prosodies
	Measurement?	Frequency Tally
	Independent Variable(s)?	± Native Speaker of English
	Measurement?	Nominal, 2 levels (NSE, Pakistani)
	Independent or repeated?	Independent
Other features?		Intact class
Statistical procedure?		Chi-Squared Test (χ^2)

7.2 Quantitative Findings

Table 21 lists the frequency (*f*) of each rhetorical prosody, with percent frequency (expressed as percentage of the total rhetorical prosodies) including the use of First/Second Person as a category in its own right. The use of Person was included in the analysis because it is understood that such use has important implications for other rhetorical prosodies. These implications will be discussed at appropriate points. A Breakdown of First/Second Person is given in Table 28 at the end of this chapter.

As we can see from Table 22, interpersonal rhetoric accounts for more than half of the total rhetorical prosodies in both samples, 70.56% in the Pakistani sample and 68.05% in the native sample, whereas textual prosodies accounts for less than one third of the total rhetorical prosodies in both samples: 31.95% in the native sample and 29.44% in the Pakistani sample.

TABLE 21: Actual frequencies and their percentages (of the total prosodies) of all Rhetorical Prosodies in the NSE and the Pakistani RA Discussions.

RHETORICAL PROSODIES	NATIVE		PAKISTANI	
	f	%	*f*	%
Imperative Mood	11	01.09	8	01.73
Interrogative Mood	7	00.69	0	00.00
Modal Verbs	269	26.61	107	23.16
Modal Expressions	200	19.78	153	33.12
Attitude/Evaluation	139	13.75	46	09.96
First/Second Person	62	06.13	12	02.60
Organising	131	12.96	52	11.25
Interpretive	179	17.70	82	17.75
Stylistic	13	01.29	2	00.43
	1011	100	462	100

TABLE 22: Main types of Rhetorical Prosodies in NSE and Pakistani RA Discussions.

RHETORICAL PROSODIES	NATIVE		PAKISTANI	
	f	%	*f*	%
Interpersonal	626	61.92	314	67.96
Textual	323	31.95	136	29.44
First/Second Person	62	06.13	12	02.60
	1011	100	462	100

Looking again at Table 21, we see that whereas the native geologists used more modal verbs, the Pakistani geologists made greater use of other modal expressions. The native geologists also used more attitudinal and evaluative comments. As for textual prosodies, the native geologists used more prosodies of the organising type whereas the Pakistani geologists used more interpretive prosodies. Similarly, the native geologists used more personal pronouns than the Pakistani geologists. In order to see whether or not the differences are significant, the data were retabulated as in Tables 23 to 27 below.

TABLE 23: Contingency table of Observed (O*f*) & Expected (E*f*) frequencies of Rhetorical Prosodies in Native and Pakistani RA discussions.

	Native		Pakistani		Totals
	O*f*	E*f*	O*f*	E*f*	O*f* + O*f*
Interpersonal	626	645	314	295	940
Textual	323	315	136	144	459
1st/2nd Person	62	51	12	23	74
TOTALS	**1011**		**462**		**1473**

($\chi^2 = 10.35$, $df = 2$, $p < 0.01$)

A Chi-Squared (χ^2) test for the overall interpersonal and textual prosodies, and Person use (Tables 22 and 23) shows that these differences are significant at the 99% confidence level ($\chi^2 = 10.35$, $df = 2$, $p < 0.01$). Similarly, a Chi-Squared test for Mood, Modal Verbs, other Modal expressions, and Attitudinal/Evaluative prosodies shows that the differences in the use of the interpersonal prosodies are also significant ($\chi^2 = 25.95$, $df = 3$, $p < 0.001$). See Tables 24 & 25 below.

Differences in the use of textual prosodies were found not significant at all (see Tables 26 and 27 below). In this comparison, Stylistic and Organising textual prosodies were collapsed (see Table 27) as the frequency of the former in the Pakistani sample was less than five (see Table 26).

Let us study Tables 23, 25, & 27 again. Comparing observed and expected frequencies in Table 23, we find that while the NSE geologists used more textual prosodies and more 1st/2nd Person pronouns, their Pakistani counterparts used more interpersonal prosodies. However, the difference in the observed and the expected frequencies only for the use of 1st/2nd Person is significant at the 99% confidence level. ($\chi^2 = 6.95$ with Yates' correction).

TABLE 24: Interpersonal Rhetoric in NSE and Pakistani RA Discussions.

INTERPERSONAL PROSODIES	NATIVE		PAKISTANI	
	f	%	*f*	%
Mood	18	02.88	8	02.55
Modal Verbs	269	42.97	107	34.08
Modal Expressions	200	31.95	153	48.72
Attitude/Evaluation	139	22.20	46	14.65
	626	**100**	**46**	**14.65**

TABLE 25: Contingency table of Observed and Expected frequencies of Interpersonal Rhetorical Prosodies in NSE and Pakistani RA discussions.

	Native		Pakistani		Totals
	O*f*	**E*f***	**O*f***	**E*f***	**O*f* + O*f***
Mood	18	17	8	9	26
Modal Verbs	269	251	107	125	376
Modal Expressions	200	235	153	118	353
Attitude/Evaluation	139	123	46	62	185
TOTALS	**626**		**314**		**940**

($\chi^2 = 25.95$, $df = 3$, $p < 0.001$)

Similarly, if we compare the observed and the expected frequencies in Table 25, we find that the native geologists used more Modal Verbs and more Attitudinal/Evaluative interpersonal prosodies than expected, while the Pakistani geologists used more Modal Expressions than expected. However, the difference in the observed and the expected frequencies is significant only for the use of Modal Expressions ($\chi^2 = 15.152$ with Yates' correction, $p < 0.001$) and Attitudinal/ Evaluative prosodies ($\chi^2 = 5.825$ with Yates' correction, $p < 0.05$).

Table 27 shows that the NSE geologists used more Organising textual prosodies than expected whereas the Pakistani used fewer Organising prosodies than expected. Similarly, the native writers used fewer Interpretive textual prosodies than expected whereas their Pakistani counterparts used more Interpretive textual prosodies than expected. However, the differences in the observed and the expected frequencies for both are not significant statistically.

TABLE 26: Textual Rhetoric in NSE and Pakistani RA discussions.

TEXTUAL RHETORIC	NATIVE		PAKISTANI	
	f	%	*f*	%
Organising	131	40.56	52	38.24
Interpretive	179	55.42	82	60.29
Stylistic	13	04.02	2	01.47
	323	**100**	**136**	**100**

TABLE 27: Contingency table of Observed and Expected frequencies of Textual Rhetorical Prosodies in NSE and Pakistani RA discussions.

	Native		Pakistani		Totals
	O*f*	**E*f***	**O*f***	**E*f***	**O*f* + O*f***
Organising/Stylistic	144	139	54	59	198
Interpretive	179	184	82	77	261
TOTALS	**323**		**136**		**459**

($\chi^2 = 0.74$, $df = 1$)

We can, therefore, conclude that the Pakistani geologists, in general, will use significantly more modal expressions whereas the native geologists will use significantly more 1st/2nd Person and Attitudinal/Evaluative prosodies. These significant differences pertain to what I have been calling Interpersonal Rhetorical Prosodies.

7.3 Discussion

7.3.1 Interpersonal Prosodies

It is a truism that "One of the most important aspects of doing science is the weighing of evidence and the careful drawing of conclusions from data" (Butler, 1990:138). This requires the scientist reporter to modulate his statements with the help of modal verbs, and other modal expressions, popularly referred to by the term, *hedges*. Hedges are "words whose job is to make things fuzzier or less fuzzy" (Lakoff, 1972:195) because, as Lakoff points out:

> natural language concepts have vague boundaries and fuzzy edges and ... consequently, natural language sentences will very often be neither true, nor false, nor nonsensical, but rather true to a certain extent and false to a certain extent, true in certain respects and false in other respects.
>
> *[Lakoff, 1972:183]*

The function of hedges is to make known to the reader the extent to and the conditions under which the propositions should be weighed and considered. As I have already remarked, a scientists cannot afford to be misconstrued.

In this connection, it is generally believed that non-native speakers of English have problems with expressing epistemicity or using hedges — "the degree of certainty with which some proposition is known or believed, or what the grounds are for such knowledge or beliefs" (Hanson, 1987:131). For example, Rounds (1982:5) thinks that expressing epistemicity is "an important problem [for non-native speakers of English] which is worthy of consideration and instructional attention" (Salager-Meyer, 1994:165). According to Salager-Meyer (*ibid.*), "The problem lies in the fact that NNSs tend to give the same weight to observed facts and interpretations." Makaya and Bloor (1987) hold the same view:

> A point frequently made in the discussion of academic writing, particularly of journal articles, is that authors need to be cautious in their claims, and it is a common weakness of inexperienced writers, in particular non-native speakers, to fail to modulate their utterances appropriately.
>
> *[Makaya and Bloor, 1987:55]*

As a result, as Makaya and Bloor (*op cit.*:66) claim, NNSE writers "make claims which strike native speaker experts as too sweeping or lacking in academic caution." However, our results seem to point to the contrary. We have found that the Pakistani geologists used more modal expressions. This calls for a discussion of underuse and overuse of hedging.

There are two conflicting views on the use of hedges which, as Salager-Meyer (1994:150) maintains, are 'not mutually exclusive'. The most widely accepted view of hedging is that they result in scientific imprecision and tentativeness, for in scientific reporting, precision and absolute statements are not always appropriate or desirable. The second view is that hedges represent the right state of the knowledge under discussion. If the state of the knowledge is such that absolute statements cannot be made, the writer will use hedges to achieve greater preciseness in scientific claims. In general, scientists use hedges "to express scientific uncertainty, skepticism, and doubt" (see Salager-Meyer, 1994:150-151).

As already discussed in Chapter 3 (section 3.3.5.1.2), a scientist may not always have sufficient evidence to assert categorically. In such a case, he will have to qualify his statements with hedging expressions. Usually, the scientist is obliged to use hedges in four situations:

1. He does not have strong conclusive evidence for the claim. This we may call the scientist's *status of evidence*.
2. He does have ample evidence but *the state of knowledge* under discussion does not allow him to make an absolute claim.
3. He does have ample evidence and the state of knowledge does allow him to make an unqualified claim, but he uses hedges to minimise the effect of these *face-threatening acts* (FTAs) (Brown and Levinson, 1978).
4. He does not have the confidence to express *commitment to the truth value of his statements*.

Geology is an established discipline with over a dozen specialised fields, each having its specialised ways of doing science; hence, the second point is not really relevant here. Let us take the other three points one by one with reference to overuse and underuse of hedges.

Salager-Meyer (1994) refers to a 'three-dimensional concept' of hedges:

1. that of purposive fuzziness and vagueness (threat-minimizing strategy);

2. that which reflects the authors' modesty for their achievements and avoidance of personal involvement; and
3. that related [sic.] to the impossibility or unwillingness of reaching absolute accuracy and of quantifying all the phenomena under observation.

[Salager-Meyer, 1994:153]

When a scientist overuses hedges, it can be interpreted in three ways: (1) the status of his evidence is poor, (2) he is being over cautious, or (3) he is not prepared to commit himself to the truth value of his propositions. In fact, the three interpretations are concomitant: poor evidence leads to over-cautiousness in making claims, and distancing oneself from the truth value of a statement that is made on the basis of poor evidence. According to Crismore and Vande Kopple (1988):

> writers use them [hedges] to signal a tentative or cautious assessment of the truth of referential information. In so doing, writers reduce the "degree of liability" or -responsibility that they might face in expressing referential information.
>
> *[Crismore and Vande Kopple, 1988:185]*

It follows that overuse of hedges may make the science overly tentative, and hence lacking in true merit.

Similarly, underuse of hedges may also be interpreted in three concomitant ways: (1) the writer has very strong evidence, (2) he is being arrogant and impertinent, and (3) he has the confidence to accept responsibility for what he claims or asserts. However, underuse of hedges may make the scientist open to attack and refutation as by sounding arrogant he violates the politeness principles: he performs an FTA in a mutually vulnerable situation without any redressive action (see Brown and Levinson, 1987:101).

There is also a further dimension to the use of hedges: their impersonal and personal uses. One can assert the objective probability of some event either without expressing any personal involvement (*It is probable; It can be said*) or with some degree of personal involvement (*Probably; We can say that*). We already know that the Pakistani geologists used very few 1st/2nd person pronouns which indicates that they avoided personal involvement.[1] This means that the Pakistani geologists used the impersonal performative (*It is concluded/suggested/ inferred*) much more than the personal performative (*We conclude/suggest/infer*). This is bound to have several important implications for the Pakistani geologist. But, first, a few observations about the use of first and second person pronouns.

The personal pronouns that realise interpersonal rhetoric in scientific writing are the first person and the second person. However, while the use of the first person singular is quite straightforward, the use of the first person plural has two interpretations: the ***exclusive we*** (Fowler and Kress, 1979), and the ***inclusive we*** also referred to as the ***impersonal we*** (Halliday and Hasan, 1976). The 'inclusive' use of *we* is more interactive than the singular *I*, as it indicates the writer's acknowledgement of the presence of the reader.

In scientific writing, the first person pronoun is widely used, while the use of *you* is rare. Sometimes interaction with the reader is struck with the use of *The reader* .... Moreover, the use of *we* and *I* may also necessitate the use of *our* and *my*, respectively. However, the use of *our* presupposes the use of only 'exclusive' *we* in the preceding text as illustrated in the following example:

(1) Therefore, **we** interpret the near-homogeneity of ***our data*** on structural state of the K-feldspar as further evidence for the pervasiveness of postcrystallization hydrothermal activity in the St. Francois Mountains complex. [NS-15]

Obviously, the use of the first person pronoun violates the condition of the *empiricist repertoire* (Gilbert and Mulkay, 1984) which implies that scientists need to depict their actions and beliefs to further the empirical aspects of their work rather than their own image as writers. As such, the writer must have strong reasons to make such a choice. The following three reasons may account for making such a choice:

[1] A Pakistani geologist, a friend, tells me that his native supervisor often changed his *It is inferred/suggested* to *We infer/suggest*. The reason he gives is that he did not feel confident enough to assert categorically even when he had strong evidence (Dr. Tahir Shah, personal communication). Another Pakistani geologist friend was rather bewildered when I told him that he could use the first person plural, *we*, even as single author. I was referring to the use of the inclusive *we*. He was not aware of this use of *we*.

1. To break the monotony of passives (Halliday & Hasan, 1976:53);
2. To indicate a shift in discourse direction;
3. To make a 'unique choice' (Tarone et al., 1985:195).

The continuous use of passives produces only a lacklustre prose. The writer needs now and again to break this monotony. The occasional use of the 'impersonal' *we*, according to Halliday and Hasan (1976:53), offers the writers the opportunity to vary their tense form from the persistent passive to the active. Thus the use of the first person not only engenders writer-reader interaction but also reduces the tiresome effect of the passive.

The writer may also use the First Person pronoun to indicate a shift in discourse or argument. It may be recalled from the discussion in Chapters 4 & 5 that a shift in discourse or argument is signalled by the onset of a new Move. The following example serve to illustrate this use of the pronoun *we*:

---

(2) The volcanic nature of the basalts in the upper parts of the Jafar Kandao Formation confirms their Late Carboniferous-Early Permian age ... Interestingly, whereas the strata older than this age are almost always cross cut by basic dykes, there is a sharp lack of basic dykes and sills in the younger (post Permian) strata (R). ***We*** assign all the plutonic and hypabyssal rocks in the Peshawar plain to this event of basic magmatism in Carboniferous-Permian. [PAK-12]

The use of *we* may also indicate a ***unique choice*** (Tarone *et al.*, 1985). According to Tarone *et al.*, (1981), "the active first person plural *we* verb form seems to be regularly used at strategic points ..." (p.135). This 'unique' choice of *we* is illustrated in the following example:

---

(3) On the other hand, raising the temperature of the system by magma mixing will promote dissolution of plagioclase. However, *we* will consider the case of decompression without magma mixing. [NS-03]

By making a 'unique' choice, the writers may also be indicating that they are prepared to accept responsibility for their actions and choices. In the above example, the writers propose a possibility, but then elect to do otherwise. Both sentences are part of the Move described as providing background information in Chapter 5.

On these accounts, most of the rhetorical prosodies can show author involvement to a lesser or greater degree depending on whether or not a First person pronoun is used. As such, *We argue* shows more author involvement and author preparedness to accept responsibility than *It is argued*. Similarly, *The reader should note* is more direct than *It should be noted*, and the imperative *Note that* is the most direct way of addressing the reader.

As mentioned above, the NSE geologists used more attitudinal and evaluative prosodies than the Pakistani geologists. Attitudinal/Evaluative prosodies include expressions such as *Unfortunately, Interestingly, It is an important point, little difference*, etc. There are several purposes for which writers may use these prosodies: comparison, approbation, disapprobation, emphasis, disputation, argumentation, and concession, etc. (see Adams-Smith, 1984). These expressions convey to the reader what the writer thinks, believes, holds, or how he feels about his claims, propositions and assertions. When the writer writes, *It is important to note*, his purpose is to alert the reader so that the point may not be overlooked, otherwise it is perfectly adequate to simply state the point without the projecting clause. Similarly, when the writer says *Unfortunately* or *Interestingly*, he wishes to convey to the reader his feelings about and attitude towards what he is about to say. Such expressions allow the writer simultaneously to state the proposition and to express his own feelings about and attitude towards it. In a comparative study of native and non-native English expository essays, Scarcella (1984) found that non-native writers differed from their native counterparts in their use of direct assertions. Whereas the native English writers used adjectives such as *important, shocking*, and *fascinating* for emphasis, the non-native English writers did not use such expressions (Scarcella, 1984:678).

7.3.2 Textual Prosodies

Although the differences between the use of textual prosodies were not significant statistically across the two datasets, usage problems were discovered in the Pakistani dataset. For well-writtennness, it is not enough to get the syntax and grammar right; there are, indeed, other subtle dimensions to writing effectively as well, particularly when reporting science. One such dimension is that of what can and cannot follow a particular textual prosody; for example, logical connectives. A writer may use several textual prosodies, but he may not be able to use them correctly. Although such problems may not be perceived readily, the reader may feel something clumsy or awkward about sentences that have such problems. One such problem we have already come across in a clause from a Pakistani text in Chapter 6 which we deferred to this chapter for discussion. Let us begin our discussion of such problems with the same example. Analogous examples from the native discussion sections are also provided for comparison.

(4a) The normal granite gneiss of Jolagram, and Jalal Kot *corresponds to Malakand granite* on the basis of their chemistry, and considered [*sic*] to be of igneous parentage and are *genetically related to the Malakand granite*. [PAK-22]

The awkwardness of the sentence results from the repetition of the same idea twice: *corresponds to Malakand granite* and *genetically related to Malakand granite*. The prepositional phrase (*on the basis of their chemistry*) adds further to the clumsiness of the sentence on account of its unsatisfactory position. Bringing it to the front may eliminate some of the clumsiness:

(4b) On the basis of their chemistry, the normal granite gneiss of Jolagram and Jalal Kot corresponds to Malakand granite ...

However, as we can see, the relation between the initial prepositional phrase and the main clause remains illogical: the chemistry of the granite gneiss provides a basis for deduction by the researchers themselves (*may be interpreted/ said to correspond* or *appear to correspond*), not for the granite gneiss to correspond to the Malakand granite.

It can, therefore, be said that the choice of an initial textual prosody constrains the selection of lexis, tense and voice in the following clause. Let us take another example of a similar nature:

(5) ***On the basis of chemical data***, the microporphyry closely corresponds with other acidic rocks ... [PAK-06]

This example also has a problem in the major clause. The textual prosody, *On the basis of chemical data*, requires in the subject position an active agent (*we infer/deduce that the microporphyry*), a projected clause (*it may be inferred/ deduced that*), or a passive after the subject of the major clause: *is found to closely correspond*. The problem seems to stem from lopsided logic: the chemical data provides a basis for deduction by the researchers themselves not for the microporphyry to correspond to other acidic rocks. No such problems were found in the NSE discussion sections, as illustrated with the following analogous example:

(6) ***On the basis of this comparison with Si shieldings***, we expect the present calculations to underestimate the change in Al- shielding with coordination number ... [NS-07]

This NSE example clearly follows what has been argued above in connection with the Pakistani example. The mental act referred to in the textual prosody is logically followed by another mental act which is the logical result of the previous act.

(7) *As concluded by Phillips (R)*, there is every possibility that myrmekites in nature form due to an interaction of metasomatic replacement and solid-state diffusion-exsolution. ***It is the petrography which would decide about the dominance of the mechanism responsible for myrmekites in a particular set of rocks***. [PAK-13]

This passage begins with a textual prosody. The main clause of the clause complex has an empty (existential) theme which presents the proposition of *the mechanism of myrmekite formation* as a possibility which is also the topic of the paragraph. The clause that follows is a cleft, and it is here that one senses a problem with cohesion. The cleft is unmotivated, for it makes the sentence appear to crop up from nowhere. The problem springs from the fact that the writer is using cleft to mark a contrast; but the function of clefts is not to achieve contrast. The grounds for contrast must either be paved in advance or be signalled with an adversative, e.g., *however*. The cleft clause is not thematically integrated within the passage which results in theme break. Let us now turn to an analogous example from an NSE discussion.

(8) Again, these figures should be used with caution, taking note of the limitations of extrapolating higher temperature kinetic data to lower temperatures, and the dangers of inferring that the reaction mechanism is the same throughout the temperature range. ***It is, however, kinetic factors and not thermodynamic stability*** that ensure long-term preservation of the marcasite structure in natural systems. [NS-02]

The cleft used in this passage clearly bears out the point I made above that clefts do not mark contrast, but focus. The writer of this passage not only uses the adversative, *however*, to signal contrast but also reinforces it by juxtaposing the two contrasted mechanisms in the initial main clause. The result is a well-knit and integrated passage.

It may lead one to believe that such problems are restricted to long textual prosodies as demonstrated above. But the following example shows that even very simple textual prosodies, such as *In conclusion*, are not free of such constraints.

(9) ***In conclusion***, it is likely that the hornblendites and at least some hornblende in the remaining rocks are of igneous origin. [PAK-05]

Here, the problem resides in the main clause. The initial textual prosody, *In conclusion*, requires that a projecting clause with a verb of the performative type (*say, state, suggest*) be used with or without a modal verb. Thus, the main clause should begin either as *we can say* or *it can be said*. However, it is a minor error, and may not be widely objected to. But there are constraints, nonetheless. The following analogous example from a native discussion obeys the constraints.

(10) ***In conclusion***, it can be said that due to the high thermodynamic variance of the corona textures described, phase diagram considerations are difficult to apply. [NS-24]

This example from the native sample demonstrates that such textual prosodies do constrain choices in the main clause. The following example illustrates a problem of a different kind. Focus is again on a textual prosody:

(11) ***In addition to** some evidence we have found for diffusion*, it will be difficult to produce the observed variety in the mineral paragenesis of the Chilas rocks by a late magmatic process. [PAK-29]

Here, the problem is with the textual prosody itself. The succeeding major clause seems to be a *non sequitur*: it states something that is not in addition to what is implied by the textual prosody, but in spite of. Replacing *In addition to* by *In spite of*, *Despite*, or *Regardless of* solves the problem. In comparison, the following NSE example does not have any problem. What is stated in the major clause *is* in addition to that stated in the textual prosody:

(12) *In addition to* increased garnet stability at lower pressures, increased Mn concentrations in the garnet suggest a Mn-rich medium in which crystallisation occurred. [NS-25]

Several initial (subordinate) dependent clauses (thematic clauses) were found to have similar problems in the main clauses. Two examples are given below with brief discussion along with one example from the native dataset:

(13) Therefore, <u>considering all the genetic and mineralogical aspects</u>, a careful examination is needed to re-classify all rocks of the Shewa Shabazgarhi complex. [PAK-06]

While the subordinate clause in this example expresses a mental act by the writers themselves, the independent clause expresses the result of this deliberation very impersonally without any involvement by the writers. What is missing from the major clause is an actor and an active verb: *we feel/think that a careful examination* ... It not only corrects the problem, but also makes it more personal. Let us now consider another example with a different kind of problem.

(14) Whereas *the external zone* of the Himalayan thrust fold belt is completely devoid of *magmatic rocks*, *they* are not uncommon in *the internal zone*. [PAK-12]

This sentence lacks the more generally acceptable principle of parallel structure. Subordinators like *whereas* require parallel meanings in the two clauses: they both must have elements of equal ranks in the subject position. However, in this example, the pronoun, *they*, and its likely referent, *magmatic rocks*, are not of equal ranks. The reference is amiss. Again, two NGs of otherwise equal status (*the external zone* and *the internal zone*) have been made unequal in terms of their participation (transitivity) in the clause complex. As such, either the dependent or the independent clause needs to be recast with either *magmatic rocks* and *they* or *the external zone* and *the internal zone* in the subject positions in the two clauses. The native dataset did not have any problem of such kind.

(15) Whereas *the K-feldspar* probably crystallized during a restricted time interval when diagenetic waters were at their hottest, *the zeolites* were subject not only to cation exchange, but also to continuing recrystallization over a much longer period, perhaps extending up to the present day. [NS-11]

This clause complex is structurally balanced: the two clauses have elements of equal rank (participants that are the focus of comparison) in subject positions. Even the processes in the two clauses are similar and hence balanced.

These examples clearly illustrate that the Pakistani geologists have problems with using textual prosodies, particularly with using logical connectives. It should also be noted that the dataset consisted of published RAs, and that they must have been through several revisions and corrections, not only by the writers themselves but also by the editors. That the errors remained point to the fact that both the writers and the editors did not notice, and therefore did not correct, all such errors. We can therefore safely conclude that the Pakistani manuscripts submitted for international publication must have, *a fortiori*, many more such problems than found in the present dataset. It will be seen in Chapter 8 whether this is really the case.

7.4 Summary and Conclusion

The purpose of this study was to investigate how experienced writers from different linguistic and cultural backgrounds employ linguistic means to attend to the needs of the readers, the demands of the discourse, and the norms of reporting science. These linguistic devices were discussed under one umbrella term, rhetorical prosodies, with two categories: interpersonal rhetoric and textual rhetoric.

Rhetorical prosodies indicate a writer's awareness of not only the text producing but also the reading process. As it is part of the rhetoric and pragmatics of language, "proficiency in this area is notoriously difficult to attain in a foreign language" (Crismore et al., 1993:40). This difficulty may stem from a number of sources: (1) some categories are used very little or not at all in the mother tongue; (2) different linguistic devices are used for some types of rhetorical prosodies; and (3) many other such devices are multifunctional in the target language (see Crismore et al., 1993:41). Recent research, mostly on Finnish writing, scientific and expository, (e.g., Ingberg, 1987; Tikkonen-Condit, 1988; Tikkonen-Condit & Liefländer-Koistinen, 1989; Mauranen, 1993) has shown that writers from different language backgrounds differ in their use of rhetorical prosodies. One common finding that these studies report is that "a certain 'implicitness' is characteristic of Finnish rhetorical strategies" (Mauranen, 1993:16). The study by Ingberg (1987) suggests a cultural rather than a linguistic cause as even L1 texts written by her subjects (Swedish-speaking Finnish students) showed a tendency to write in an implicit style. It thus seems that the use of such devices is determined by the linguistic traditions of a culture.

As discourse level contrastive research is not anywhere available on expository or scientific writings in Urdu, at least to my knowledge, it is therefore, impossible to give reasons for the Pakistani writers' extremely impersonal style. It would appear that the Pakistani authors follow the strategy of "let facts speak for themselves". It may be said that they do not attempt to strike "a delicate balance between rigorous anonymity and obtrusive personality" (Corbett, 1981:217). The balance is described as delicate, for excessive use of rhetorical prosodies may be as disadvantageous as limited or no use. On the one hand, they may interfere with the reading process, and, on the other, they may look outright imposing and condescending. The reader may think that he is not being given a chance to interpret things for himself.

Maintaining impersonality in their indigenously published papers does not seem detrimental, but not asserting themselves when it is due and important for their claim or viewpoint may result in anonymity, or it may be construed by their native counterparts around the world as lack of confidence or the result of vagueness. It will be seen in the next chapter whether it is really the case by looking at native referees' comments on Pakistani geology RA manuscripts.◆

TABLE 28: Frequency breakdown of First/Second Person Pronouns in the NSE and the Pakistani discussions with mean per discussion frequency.

	NATIVE		PAKISTANI	
FIRST/SECOND PERSON	***f***	**MEAN**	***f***	**MEAN**
WE	39	1.30	8	0.27
Our	16	0.53	4	0.13
The Author	1	0.03	0	0.00
I/my	3	0.10	0	0.00
One (of us)	1	0.03	0	0.00
The reader	2	0.07	0	0.00
	62		**12**	

CHAPTER 8

From the Referees: NS evaluation of Pakistani RAs

8.0 Introduction

So far we have been looking linguistically at the genre and discourse features of the research article to discover differences in the native and the Pakistani RAs. This chapter looks at the Pakistani scientific writing from another perspective: from the perspective of native editors and referees. The aim is to corroborate or disprove the findings so far accumulated. The study uses real data, actual records of referees' reports — not retrospective comments by editors as in Gosden's (1992) study. It will be seen whether or not the features so far identified in the Pakistani RAs (as different from those of the native RAs) are really problematic. If they are found to be problematic, they will have to be addressed rigorously. This study will also judge whether such linguistic analyses are indeed useful.

8.1 Method and Materials

Seven referees' reports on five manuscripts submitted to international journals (US and UK based) were obtained from the authors along with three manuscripts with corrections and specific comments. Manuscripts of the remaining RAs were not available. Breakdown of the data is as follows:

1. Two detailed reports from two referees on one manuscript. (With manuscripts.)
2. Two detailed reports from two referees on one manuscript. (No manuscripts.)
3. One detailed report from one referee. (No manuscript).
4. One brief report along with manuscript.
5. Letter with comments along with manuscript.

The reports were carefully studied and all comments, both general and specific, were marked. Similarly, the manuscripts were also scanned for comments and corrections. Four of the five detailed reports started with general comments followed by comments on individual sections including the title and the abstract.

8.2 Findings and Discussion

8.2.1 General Comments

Six important general comments about four manuscripts were found. As two manuscripts had comments by two referees each, they are presented as paired examples. The referees, in both cases, provide somewhat contrasting views:

(1) I think that a revised form of the paper will be a ***major*** contribution to our present understanding of ... and I therefore strongly encourage the authors to develop this work. However I feel that the paper is, at present, only in a ***first draft*** form, and requires a lot of attention to get to a final draft stage. I am most concerned that the authors don't ***sell themselves short***, as I consider the data and models discussed in this paper to be of fundamental importance to our understanding of ...

(2) There are a number of problems with this paper and I suggest a ***severe*** re-write before it can be accepted for publication. In addition to the obvious grammatical errors there are also problems with the geochemical presentation, interpretation and discussion.

(3) This paper provides ***one of the best examples*** of ... that I have yet encountered; it is therefore well worth publishing. However, I believe that ***it is plagued by some fuzzy thinking*** and that it would be greatly benefited by being re-written.

(4) [W]hile there isn't anything in the manuscript that is incorrect, there isn't anything that furthers our knowledge of the phenomenon either.

While comments (2) and (4) betray a negative approach on the part of the referees, comments (1) and (3) are very positive. They are balanced in that they contain praise as well as criticism. It is quite interesting that the two manuscripts receive a negative and a positive review though the two manuscripts were recommended for publication by both their respective referees. Comment (1) supports the findings already discussed in previous chapter that not asserting oneself when it is due and appropriate may result in non-appreciation and anonymity. It may be because the authors did not thoroughly stress their argument that the second referee (2) failed to appreciate the merits of the paper. Various comments on the manuscript itself by the two referees lend support to this argument. For example, the first referee notes at one place: *it is* *well worth adding here that similar sedimentary sequences are located near ... (R), and [also in] your recent mapping in .... This adds weight to your argument.* He further notes: *you should discuss how ... emphasises a tectonic contact between the ... + ... [and] why you don't agree.* The referee also changes, at one place, "The former are suggested to be" to *The former are interpreted as* which makes the statement more assertive. The second referee also makes numerous comments of a general nature on the manuscript which are meant to strengthen the authors' argument. For example, he advises the authors to use *apparently* sparingly, by asking *why only apparently* at one place and commenting *too vague, either it is or it isn't* at another when the authors write "appear to be intrusive." At another place, the referee urges the authors to *emphasise the ... as these seem to be the best evidence for relative age dating.* At yet another place, he inquires: *if the heterogeneity of the mantle source is important to your arguments, it must be demonstrated more clearly than by referencing fairly similar spidergrams.* Referring to a statement, he remarks: *This is a very dubious statement considering that the LIL elements are so mobile and that the rocks are at amphibolite grade!!* Similarly, the second manuscript did not make sufficient impact on the second referee (4) because, in the words of the first referee (3), it was "plagued by some fuzzy thinking." But no remarks on the manuscript were found to supplement the said comment.

The following two statements also point out some important deficiencies in the remaining two manuscripts. They are both similar in that they are concerned with interpretation. While the first is alleged to suffer from rigorous but dubious interpretation, the second lacks enough detail to support the interpretation.

(5) the positions of the data points are ... ***being interpreted in too rigorous a manner.*** I thus favour only pointing out that the data plot near both the mantle and orogene curves, and not going further to make ***any more dubious interpretations*** on the basis of what is a very generalized (and in many cases conceptually based) model.

(6) In particular, I think that the paper would benefit from more ***detailed discussion of how you arrive at your interpretation***.... Further background on the geologic setting would be very helpful, as would greater emphasis on each of the three stages of evolution of these samples.

The first comment, (5), is supported by a few other remarks as contained in the report. Take, for example, the remark that *the data are much more consistent with an orogene or mantle source than they are with a lower crustal source* which results in the plots' *not support[ing] a lower crustal origin* as attempted by the authors. The manuscript does not have any important remarks to further the discussion. However, the last manuscript contains a few brief remarks that call for more detailed discussion. Remarks such as *on what basis, describe assemblage before interpreting it, what is this? It isn't described above, nor is it shown in Fig. 1, describe your reasons assuming the veins are high-P*, and *what are these grounds* point to missing details.

8.2.2 Comments on Introduction

Not all reports commented on the introductions. Only two such comments were found that pointed out vagueness of purposes. The examples are given below:

(7) Define more precisely what the paper aims to do and what methodology will be adopted.

(8) The intention of the second paragraph is unclear and should be reformulated.

These remarks by the native referees support the findings that the Pakistani authors did not always make it clear what they wanted to achieve by the study being undertaken (see Chapter 4). It should be recalled that ten Pakistani introductions did not have a Move 2 (*Establishing a Niche*) at all, that three had it embedded in Move 3, and that a few did not define their purposes in unequivocal terms, though all had a Move 3 (*Occupying the Niche*). If the purpose is too broad or too vague, the researcher is likely to get lost, and not arrive at any conclusions. The following excerpt is from the first manuscript:

> In this paper, we explore variations in the geochemical composition of successive phases of magmatic activity in the (...) amphibolite belt and the (...) mafic-ultramafic complex from southern (...).

Though the purpose has been announced, a question may still arise: 'To achieve what?' It, therefore, seems unlikely that we will find a concrete conclusion in the discussion. But there is a solid conclusion:

> The magmatism in the southern (...) had distinct geochemical character in successive phases of magmatic activity, which can be used to characterise changes in the tectonic setting of magma generation within the interoceanic life span of the (...) island arc. [Followed by three numbered paragraphs.]

This conclusion, however, responds to what was claimed in Move 2 of the introduction: *However, the interoceanic stage of arc growth is still poorly understood.* Move 3 simply states the means for arriving at an understanding of the phenomenon, which is not clear from the purpose itself. The referee is, therefore, right in remarking that the aim of the paper needs to be defined clearly.

In the absence of the manuscript, it is not possible to evaluate the second comment (8) above; however, the authors seem to have made good the deficiency in the published paper.

8.2.3 Comments on Discussion/Conclusion

The discussion and the conclusion sections received the most comments. As some of the referees did not mention the section while making notes, only those reports that arranged the comments RA section-wise are considered. The following comments are most important as they point out several problems that need to be addressed. First, there are problems with interpretation:

(9) It would be perhaps instructive to compare some of the signatures observed in the (...) and (...) lithologies to those from modern-day arcs. ***This will make not only your interpretation more valid*** but it may also shed some light on the combined tectono-magmatic history.

(10) In particular, I think that the paper would benefit from more detailed discussion of ***how you arrive at your interpretation***....

I believe the second comment points to a more serious problem than the first one. It may be that the authors do not develop their interpretation through discussion and argument which make it appear dubious and suspicious. Although the first comment is only a suggestion, it points to the authors' not taking other possibilities in their stride. The following comments further point to this problem:

(11) You virtually throw away the fact that there are some (...) trondhjemites within the (...) Complex. This is a great discovery and supports the idea that the (...) rocks are melts of arc volcanics — probably melts of the (...) caused by the intrusion of the (...) Complex. If this is the case it has important implications for the timing of intrusion of the (...) Complex into the (...).

(12) You must discuss the differences between your intrusive model relating to the (...) Complex versus (...) tectonic/ shear model.

(13) As it stands there is no mention of element mobility and until this is fully addressed much of what has been discussed in the paper is dubious to say the least.

(14) it might be possible for the authors to argue that unexsolved spinels in the same rock have evolved to the same composition and these represent the other half-bracket.

(15) More emphasis could be given to the observation that alkali pyriboles appear in the fenites only after the elimination of the aluminous phase (phengite).

(16) Cross-reference your discussion more with your tectonic model diagram.

(17) The discrepancy between the modal and calculated composition of zone-3 rocks (...) is not commented on.

(18) The statement (on p.12) regarding the composition of biotite and phlogopite in fenites is sweeping.

All these comments point to limitations of one kind or another in the Pakistani discussions: omission of or lack of emphasis on important issues, lack of cross-referencing, unsupported statements, and failure to consider other possibilities. Ultimately, such oversights are bound to have adverse consequences for the conclusions. The following comments point to such shortcomings. They range from remarks on lack of support for conclusions (19, 20), omitted conclusions (21) to overall merit of the conclusions (22):

(19) The recent model by (...) needs to be *fully* discussed in the light of the conclusions made in this paper.

(20) The authors should present amphibole analyses to show evidence for their conclusions here.

(21) Whilst there some [sic.] very important conclusions discussed included [sic.] in the present text, there are some equally important conclusions omitted from the discussion.

(22) The conclusions reached are to a degree disappointing in that no general petrogenetic inferences are presented.

Lack of focus can obfuscate one's own thinking, hence the charge of 'fuzzy thinking' (3). Having a clear purpose is vital for presenting a sound argument and well-knit discussion. It would appear that the Pakistani discussions lack direction which prompts one referee to remark (1): *This requires much more planning as it is not clear what is being discussed.* It appears to be a usual problem with NNS researchers as 28% of Gosden's (1992:132) editor respondents termed 'clear and logical presentation of results/ discussion' as crucial for acceptance:

As seen by editors in this field, the crux of the presented argument lies in the rhetorical

> manipulation of discourse in explaining "what you did, why, what you found out and what you interpret from this." This is reflected in the large number of comments on the need for clarity and precision in evaluating relevant research and making claims.
>
> *[Gosden, 1992:132-33]*

The greater number of comments on the discussion section reveals that this section is the most important. It would appear that the fate of a paper submitted for publication depends more on the discussion than the introduction. The introduction section, as already argued above, provides the focus that is so essential for the well-formedness of the argument and the discussion.

Other sections also received similar remarks from the referees. A few of the most important comments are given below to shed further light on the problems identified. The referees urge the writers to furnish analytical details (23, 24), support their statements (25), be brief at some places (26), integrate text and figures (27), and write in a confident style by avoiding the use of *apparently* (28). The last remark (29) is general as it refers to an entire section.

(23) Include some analytical details. At the moment the reader doesn't know when or how the data was produced.

(24) Add a brief paragraph or two describing the analytical techniques.

(25) The second paragraph presently consists of two unsupported statements.... I am not at all convinced by the supposed 'heterogeneity' — this needs some further thought, or deleting.

(26 The "brief description of petrography and mineralogy" occupies 3½ pages! It contains much repetition and irrelevant detail and undoubtedly could be shortened to 1½ sides.

(27) You do ***not*** integrate the text with the Figures at all!!

(28) This section should be written in a more confident style (avoid the use of apparently, especially when used to describe intrusive features).

(29) This section requires some general tidying up — see suggested changes marked on the manuscript. (manuscript not available)

8.2.4 Comments on Language/Grammar

While several grammatical and stylistic errors were corrected by the referees themselves, others they left for the authors to correct. Such corrections usually pertained to overlong or vague sentences. The referees pointed out such desirable corrections with comments, such as, *rephrase this sentence*, *cut this sentence down*, etc.

Errors that were easy to understand and quick to correct were always corrected by the referees; for example, the referees changed ***This is also true that*** to *It is also true* *that* (cf. *This is also true of*), ***also establishes*** to *strongly suggests*, ***is interpreted to represent*** to *is interpreted as representing*, ***suggested to be*** to *interpreted as*, ***attributed mainly to*** to *because of*, ***reflect*** to *imply*, and ***The subsequent discussion*** to *The following discussion*.

Also at places, the referees made additions and deletions to make sentences clearer or shorter, ranging from minor changes (Examples 30 & 31) to change of phrases (Examples 32 & 33) and transformation and rephrasing of sentence structure, involving fusion of two sentences (Examples 34-38). The last example (39) shows an unsuccessful attempt by the writer to make a long NG the subject of the clause which result in a very clumsy construction. The referee changes the NG to a clause. A few examples are given below. The original sentences are given first, followed by the corrected ones.

(30a) ... more than two third of the amphibolite belt is plutonic, intrusive in the metavolcanic amphibolites.

(30b) ... more than two thirds of the amphibolite belt is plutonic, with a metavolcanic country rock host.

(31a) The Chilas complex is 300km long and up to 40km broad stratiform mafic-ultramafic body apparently intrusive into a basement made up of early arc basalts ...

(31b) The Chilas complex is 300km long and up to 40km wide, and is a broad stratiform mafic-ultramafic body apparently intrusive into a basement comprising early arc basalts ...

(32a) However, the intraoceanic stage of arc growth is still poorly understood.

(32b) However, history of the arc prior to collision is still poorly understood.

(33a) These igneous complexes were emplaced prior to and were deformed during the 80-90 Ma. Kohistan-Karakoram plate collision, and thus truly represent the intraoceanic stage of arc growth ...

(33b) These igneous complexes were emplaced into arc lithologies and were deformed during the 80-90 Ma. Kohistan-Karakoram plate collision, and thus represent part of the intraoceanic stage of arc growth ...

(34a) The UMA association contains streaks and thin layers (mostly < 3 cm) of Cr spinel (Cr_2O_3 up to 39 wt%) that may be cut off, disrupted, pinched and swelled. There are also local lenses less than half a meter across.

(34b) The UMA association contains streaks and thin layers (mostly < 3 cm) of Cr spinel (Cr_2O_3 up to 39 wt%) and lenses less than half a meter across.

(35a) Such a variation, excluding exsolution, is seen in many thin sections. It is generally less pronounced in the segregated spinel and exsolved magnetite ...

(35b) This variation is generally less pronounced in the segregated spinel and exsolved magnetite ...

(36a) The variation in the spinels (along the solvus or otherwise) leads to the conclusion that they adjusted themselves to falling temperatures by reaction with adjacent silicate grains (olivine, pyroxenes, and hornblende).

(36b) The variation in the spinels is most likely the result of reaction with adjacent silicate grains.

(37a) Orthopyroxene status is not clear in terms of primary vs coronitic origin.

(37b) It is unclear whether orthopyroxene is of primary or of coronitic origin.

(38a) Opaque oxide minerals were not paid sufficient attention during this work, except one analysis which is pure magnetite with low ...

(38b) A single analysis of an opaque oxide yielded pure magnetite with low ...

(39a) These higher than the magmatic pressure estimates mean that the coronas developed during burial rather than exhumation.

(39b) These pressure estimates are higher than the magmatic pressures and imply that ...

In addition to minor deletions, the referees sometimes crossed out entire paragraphs as *unnecessary*. Two paragraphs (more than one page in length) were crossed out in this way from one manuscript.

8.3 Summary and Conclusions

In a survey, similar to that carried out by Gosden (1992), Davis (1985) asked 85 journal editors from professional scientific and technical societies to point out common mistakes made by contributors to their journals. They pointed out that contributors usually:

1. fail to show problem or significance of results;
2. fail to make a case for their research;
3. tend to give too long, overly detailed information.

These comments clearly support our findings. In addition, the editors advised their contributors to clearly show the significance of the work to the reader and to the field, to emphasise what is relevant, and to state the problem, and results. Our findings clearly reveal that the Pakistani geologists do have some similar serious problems with language and expression, clarity of thought and argument, the discussion and interpretation of findings, and the making of logical and valid conclusions. As such, these findings not only support the findings that we discovered through genre and discourse analysis, but also enhance the reliability of and one's confidence in such analyses.

As all the manuscripts discussed above have now been published, it is hard to accept that the problems pointed out by the referees were due to 'poor science'. Although it may be true that "poor science often indicates poor thinking and therefore poor expression and presentation" (Gosden, 1992b:133), it is not necessarily true that poor expression and presentation indicate poor science. According to Gosden (1992b), good science cannot be obscured by poor expression; however, "mediocre science combined with mediocre communication is a potential problem" (p. 133). The problem lies in the fact that what the native speakers view as poor expression and poor presentation, may not be considered so by the non-native readers. As pointed out in Chapter 2, scientific inquiry is an international, universal activity, and has acquired universal norms and conventions. Scientists who wish to contribute to this universal inquiry, must follow the conventions and norms of scientific reporting: how to assert, argue, persuade, and make claims, etc. And as the bulk of scientific reporting is done in English, they need to follow the discourse conventions of the English language, too: theme and theme development, information structure, topic continuity, and paragraph structure, etc. Not following the universal rules of science as embodied in the language of international scientific communication — English — may render a scientist's report suspicious in the eyes of the universal scientific community that follows these norms and conventions.

The problems so far identified in the Pakistani geology RAs have to do with both the universal rules of scientific reporting and the discourse conventions of the English language. They must be addressed if the said geologists wish to make their work known to the outside world. This is what I attempt to achieve in the next chapter, pedagogical implications.u

CHAPTER 9

Pedagogical Implications

9.0 Introduction

This chapter is concerned with treating the problems we have identified during the course of this study. Four areas of major concern have been identified:

1) In Chapter 4, we discovered that as many as ten (33.33%) Pakistani RA introductions did not have a Move 2 (*Establishing a niche*) (26.67%) at all, four had a suspect Move 2 (13.33%), and three had a very vague purposive Move 3 (10%). It should be recalled that in the introduction the researcher needs to address "the goals, current capacities, problems and criteria of evaluation that derive from and operate within [the] discipline" (Zappen, 1983:130). The NSE referees' comments as discussed in the preceding chapter corroborate this finding.

2) In Chapter 5, we compared the Pakistani RA discussions with the NSE RA discussions in a number of ways. As a result, we discovered that the Pakistani discussions had a shorter Move 2, the move concerned with the discussion and interpretation of findings, and that many of the Pakistani geologists did not provide a main conclusion or macroproposition. This is a serious flaw which may lead to rejection of the manuscripts by an international journal as according to Day (1979):

> *Many* papers are rejected by journal editors because of a faulty Discussion, even though the data of the paper might be both valid and interesting. Even more likely, the true meaning of the data may be completely obscured by the interpretation presented in Discussion, again resulting in rejection.
> *[Day, 1979:33]*

A comparison with the introduction section revealed that this was due to not having a clear purpose or focus in the introduction. The NSE referees's comments also corroborate these findings.

3) In Chapter 6, we looked at theme choice and method of development. It was found that the Pakistani geologists used fewer interpersonal and textual themes than their native counterparts. In addition, they were found to use more postponed themes. Moreover, the Pakistani geologists had problems with chaining topical themes to have a consistent method of development. Some of the NSE referees' comments on the manuscripts may be construed as having to do with this problem.

4) In Chapter 7, we contrasted the Pakistani discussions with the NSE discussions with a view to discovering the relative use of rhetorical prosodies (*interpersonal* and *textual*). On the whole, the Pakistani geologists used fewer interpersonal prosodies though they used more modal expressions. The difference was more marked in the use of First Person pronoun. Greater use of modality and much lesser use of First Person pronouns make the Pakistani discussions more tentative and more impersonal showing less author commitment. As a result, the Pakistani geologists are less assertive in their claims. As assertions need to be substantiated with data and results, lack of clear assertions might be construed as not having enough confidence in one's data or results. Some of the NSE referees' comments support these findings.

In addition, the referees' comments on Pakistani RA manuscripts (Chapter 8) submitted for international publication not only supported the findings we found through genre and textual analysis, but also pointed to some other areas of concern, such as omission of or lack of emphasis on important issues, lack of cross-referencing, unsupported statements and conclusions, failure to consider other possibilities, and, above all, the likelihood of their 'selling themselves short' as one referee commented.

It appears that the first three problem areas have to do with what Flower and Hayes (1980:34) refer to as three main constraints that a writer needs to deal with: integrating knowledge; linguistic conventions; and the rhetorical problem. By integrating knowledge, Flower and Hayes mean "the task of transforming incoherent thought and loosely related pockets of information into highly conceptualized and precisely related knowledge network" (*ibid.*). Linguistic conventions also constrain the process of writing: "even the ... experienced writer must encounter the inevitable truculence of language itself, which seems to resist our attempts to form a set of continuous sentences with forward and backward reference" (*op cit.*:36). The rhetorical problem imposes a number of demands on the writer. It not only controls the *purpose* in writing, but also the sense of the *audience* and the *projected self* or imagined roles. In fact it directs the entire process of writing (*op cit.*:40). Collins and Gentner (1980:52) specify similar constraints for the process of writing: content, structure, and purpose.

The participants in this case already have the content knowledge, but they may not be consciously aware of the internal/rhetorical organisation of the RA sections. As the "rhetorical structure is the first defining parameter of the scientific article ..." (Wood, 1982:128), "an explicit description of the way in which texts are organised will be helpful to teachers and learners alike" (Hopkins & Dudley-Evans, 1988:113). Hopkins and Dudley-Evans suggest that a writing task is a 'communicative event' which needs to address those features of the text which relate to:

1. The content of the speaker/writer's message.
2. The internal logical organisation of what is being presented, and the implicit and explicit patterning introduced by speaker/writer.
3. The ways in which the speaker/writer takes account of his audience.

[Hopkins & Dudley-Evans, 1988:114]

Research in *schema theory* has convincingly demonstrated the relevance of *formal* schemata to the teaching of reading and writing (Carrell 1984a:104). A link between genre and schemata has also been proposed (Hewings & Henderson, 1987). Swales (1990) too acknowledges the role of schemata in genre-based studies. He holds that there exists an intrinsic relationship between the two (p. 88). Carrell (1983:83) distinguishes between *content* (cf. *rhetoric of content*; Billig, 1987) and *formal* schemata (cf. *rhetoric of form*; Billig, 1987). Content schema relates to the background knowledge the reader or the writer has about the information in a piece of text while formal schema refers to the way that information is logically and rhetorically organised. Carrell argues that both are necessary for comprehension. Researchers have been able to demonstrate the relevance of formal schema to ESL reading and writing (see Carrell, 1984a for a review). In yet another study, Carrell (1984b) ventures to propose that ESL readers would appear to be similar to native readers if the former "possess the formal schemata against which to process the more highly structured types of discourse" (p. 464). As the NNSE scientist-researcher already possess the content schemata of their fields, explicit teaching of the structure of the RA, which indeed is a 'highly structured type of discourse', would help them write well. Carrell (1984b:465) therefore suggests that it would be highly fruitful to devote instruction to identifying the discourse structure of the genre being taught. It follows that learning to write RAs, or any genre, for that matter, involves a number of prerequisites:

> The acquisition of genre skills depends on previous knowledge of the world, giving rise to *content schemata*, knowledge of prior text, giving rise to *formal schemata*, and experience with appropriate tasks.
>
> *[Swales, 1990:9-10]*

It is only through extensive reading that one can acquire the world (content) knowledge necessary for this purpose. The non-specialist English instructor cannot help the learners in this regard. His help can only be sought in learning the *formal schemata* of the genre. Genre analysis aims to equip the English instructors and academics to do this job in a befitting manner: "In the research world, the aim is to help people achieve a level of competence that, in career-related genres at least, surpasses that of the average native speaker" (Swales, p. 10).

9.1 Framework for Addressing Problems

Now that we have a list of all the problem areas and views of some experts in the field about the utility of explicitly teaching the rhetorical structure of the research article genre, we face the crucial question of how to proceed to address the problem areas. Given that we are dealing with professional, experienced researchers, we cannot rely on textbooks that are mostly meant for students and novice writers. Using such books would certainly be counterproductive. And if remedial tuition is to be arranged for the said NNSE geologists at all, it must be in the guise of informal sessions (workshops and seminars), rather than in the form of classroom teaching. It is essential to gear the instruction to the type of audience. Furthermore, while some of the problems can be addressed through such tuition, others that have to do with thinking and concept formation cannot be dealt with in this way. Noting that teaching cannot guarantee an improvement in the learner's thinking processes, Gage (1986) states:

> This is the case, presumably, because some of a writer's activities are assumed to be teachable while others are assumed to be unteachable. Sentence structure, grammar, mechanics, organizational forms, heuristic procedures — these are teachable. Having ideas, being sensitive to issues, caring about whether one is right, taking responsibility for finding good reasons — these are not teachable. So, even while it may be admitted that the latter activities, or attitudes, are essential for writers, these are not among the "skills" that technical methods teach. Students are assumed to be able to gain them on their own, at some point after the skills are mastered.
>
> *[Gage, 1986:14-15]*

The teaching of writing, therefore, is not a straight forward affair. However, the type of audience that we are concerned with give us ample leeway to structure the instruction. We can have workshops, seminars, brainstorming and awareness-raising sessions, etc. It is in this spirit that the activities outlined below are proposed. The activities are all participatory; that is, the participants will be required to take part in the activities. Following the rationale presented above, I propose to address the four problem areas one by one through a series of sessions comprising seminars and workshops.

9.2 Proposals and Activities

9.2.1 Sessions on Introduction

9.2.1.1 Preamble

A series of five sessions comprising seminars/workshops are proposed for the presentation of the rhetorical/schematic structure of the RA introduction: a general session concerned with raising the awareness of the participants that a conscious knowledge of the structure of the introduction is useful, followed by three such session taking up the three Moves one by one, and a final cumulative session to consolidate the learning experiences of the first four sessions. Each session will be of one hour duration; however, the sessions may be extended by up to half an hour if possible.

Swales (1984:85) has shown that scientists who write and publish research articles have only an implicit, unconscious knowledge of the rhetorical organisation of the introduction. Swales proposes an activity which exploits the scientists' unconscious knowledge in order to raise their awareness that an explicit knowledge can not only be helpful in reading but also in writing. And according to Hyland (1990:77), "the structure of a text contributes significantly to the realisation of the meanings it contains and ... a clarification of this structure can be an important pedagogical resource." Swales reports that none of those who tried this activity succeeded in arranging the sentences into their original sequence. Giving his reasons for the unexpected difficulty of the task, Swales argues that "those attempting the exercise could not call upon any useful expectations as to how the Introduction might be arranged ..." (p. 86). However, when the participants were asked to have another go after they were apprised of the rhetorical structure of the introduction section, "the success rate climbed from 0% to about 50%."

9.2.1.2 General Session and Activities

The activity proposed by Swales is well-suited to the situation we are dealing with and it can be used as described by him without any modification. This session will have the following 8 procedures:

SESSION 1

1. **Activity 1:** The participants are given several jumbled sentences along with the title of the RA. They are asked to put them in order to make a coherent introduction. (It is important that the introduction be short with a fairly regular structure. For a start, I would use the following introduction [NS-24].
    a. The gabbroic rocks at Black Hill (about 85 km E of Adelaide) intruded at relatively low pressures after the end of regional metamorphism and have not experienced any metamorphism subsequently and are thus pertinent to the debate mentioned above.
    b. Coronas are usually described from metamorphosed gabbros and consequently have often been interpreted to be associated with protracted cooling during the metamorphic event (e.g., Mongkoltip and Ashworth, 1983).
    c. Here we report on new symplectitic reaction coronas between olivine and plagioclase in gabbroic rocks from Black Hill, South Australia.
    d. Reaction coronas between olivine and plagioclase are a common feature of many gabbroic rocks.
    e. Low-pressure corona textures between olivine and plagioclase in unmetamorphosed gabbros from Black Hill, South Australia.
    f. The physico-chemical conditions during corona formation are not only different from many of those described in the literature, but their formation is well constrained by the conditions during crystallisation of the magma as the coronas must have formed during initial igneous cooling.

g. In general, such coronas formed at high pressures and are associated with garnet and/or spinel plus clinopyroxene as reaction products (see Nishiyama, 1983 for a review).
h. However, there has been some considerable debate over this metamorphic versus igneous origin (e.g. Joesten, 1986a and b; Ashworth, 1986).

[Correct order: e-d-g-b-h-c-a-f]

The participants are given a chance to discuss their experiences with one another. Their views as to the problems encountered during the activity are noted.

2. ***Presentation:*** A description of the genre structure of the introduction is presented along with a description of the linguistic elements that usually signal the onset of the Moves and Steps.
3. ***Activity 2:*** The participants are asked to have another go.
4. ***Discussion***: At the end of the activity, they are asked to rate their success on the activity and whether any of the problems they encountered in the beginning were solved.
5. The participants are asked to comment on the appropriateness and practical utility of the model.
6. ***Activity 3:*** Time permitting, they are given another set of jumbled sentences, this time comprising a longer introduction.
7. ***Discussion***: A discussion follows.
8. ***Follow-up:*** To motivate them to explore further for themselves, they are given a copy of the model and asked to analyse the introductions they have already written and see whether they can find any problems with them and whether they can improve them in the light of their experiences in the seminar.

9.2.1.3 Sessions on Individual Moves

There will be a total of four workshops, one each for the detailed treatment of the three Moves/Steps and the fourth for consolidating the learning experiences from the first three. As the first three workshops are structured in a similar way, detailed breakdown of only the first session is provided as an example.

SESSIONS 2-4

Move 1: Establishing a Territory

1. ***Presentation:*** At the start of the session, a presentation is given about the purpose of Move 1 and the steps comprising Move 1, and their linguistic realisations.
2. ***Activity 4:*** The participants are given a number of Step 1.1 (*Claiming centrality*), Step 1.2 (*Making topic generalisation*), and Step 1.3 (*Literature Review*) sentences from different introductions. They are asked to identify those sentences that realise the three steps and to group them so that each group make a complete Move 1. With their

specialist knowledge of the discipline, they should be able to group the Steps after they had identified them.

3. ***Discussion:*** The participants are encouraged to discuss their experiences, and to point out the problems they encountered during the task.
4. Sessions on the same pattern are arranged for Moves 2 & 3.

9.2.1.4 The Cumulative & Follow-up Sessions

This session will have two objectives: to consolidate the previous learning experiences, and to make the participants conscious of the relative importance of the Moves. The following activity is proposed for this session.

SESSIONS 5-6

1. **Activity 5:** The participants are given 2 or 4 introductions (depending on the time available) with the instruction to rank them according to whether an introduction has a clear focus and purpose. To let them see the importance of Move 2, it may be necessary to omit the Move 2 altogether from one of the introductions.
2. **Discussion:** The activity over, they are asked to give reasons for their decisions. Their responses are written on the board or displayed on the overhead projector.
3. **Presentation:** The participants are informed that the reader of a research article usually wants to know *why the research was undertaken*, *how it was undertaken*, and *what was the outcome*. In addition, the reader may want to know what the author wanted to achieve by his research. Lack of focus results from not having a clear purpose which may in turn be a consequence of not having a research gap to fill, a research question to raise, or a problem to solve. It is brought to the notice of the participants that a clear focus/purpose depends on Move 2, *establishing a niche*, and on stating how this niche is to be occupied by the research about to be reported. This way, the participants will be able to see the importance of Move 2 as well as that of Move 3. It is hoped that this will solve the first problem.
4. **Discussion:** The participants are encouraged to raise questions about the matters brought up in the presentation.
5. **Follow-up:** The participants may be asked to analyse the introductions they have already written and published and to report back (if willing) in a follow-up session what revisions they would make. As this session depends on what the participants report, it is kept open-ended. This session will be in addition to the one discussed below.

9.2.2 Sessions on Discussion section

9.2.2.1 Preamble

I propose to use the same activity for presenting the rhetorical structure of the discussion section to the participants as proposed for the introduction section. Given that the RA discussions are usually longer and more complex, it is much more important to have a very short discussion. I suggest that the discussion should not exceed 20 sentences at the most.

9.2.2.2 General Session and Activities

SESSION 7

1. **Activity 6:** The participants are given several jumbled sentences along with the title of the RA. They are asked to put them in order to make a coherent discussion section. (It is very important that the discussion be short with a fairly regular structure.

2. **Presentation:** In view of the fact that the discussion section has considerable cyclicity of Move 2, it will not be a good idea to present the rhetorical structure of the discussion section in linear form. I therefore propose a decision flowchart instead (see Figure 14 below). It has the advantage of prompting the writer to make decisions at every stage. This will help him think about how to organise the discussion.

   The flowchart begins with asking the question: "Was the study based on a hypothesis or research question (RQ)?" Although it may appear odd to ask this question at this juncture, it is important, for it helps the author to focus on what he might have forgotten. If the answer is 'Yes', he is asked to restate his hypothesis or RQ, else he should reiterate his purposes. Next, he is asked whether any specific methods were used. If the answer is 'Yes', he goes to the box that advises him to describe the methods in brief, otherwise he goes straight to reviewing some relevant background literature. It should be noted that in the linear model, these first two steps have been collapsed into Step 1.1. From here, the writer goes on to state his findings, interpreting and comparing them with previous findings, etc. The flowchart also provides for returning to 'state findings' box if necessary, that is, if the writer has other findings to report.

   As can be seen, every finding is passed through the same stages. The possibility of any finding being inadequately discussed (a weakness that was found in the Pakistani discussions) is thus precluded.

3. ***Activity 7:*** The participants are asked to have another go.

4. ***Discussion***: At the end of the activity, they are asked to rate their success on the activity and whether any of the problems they encountered in the beginning were solved.

5. The participants are asked to comment on the appropriateness and practical utility of the model and the flowchart.

6. ***Activity 8:*** Time permitting, they are given another set of jumbled sentences, this time comprising a longer discussion.

7. ***Discussion***: A discussion follows.

8. ***Follow-up:*** To motivate them to explore further for themselves, they are given a copy of the model and the flowchart and asked to analyse the discussions they have already written and see whether they can find any problems with them and whether they can improve them in the light of their experiences in the seminar.

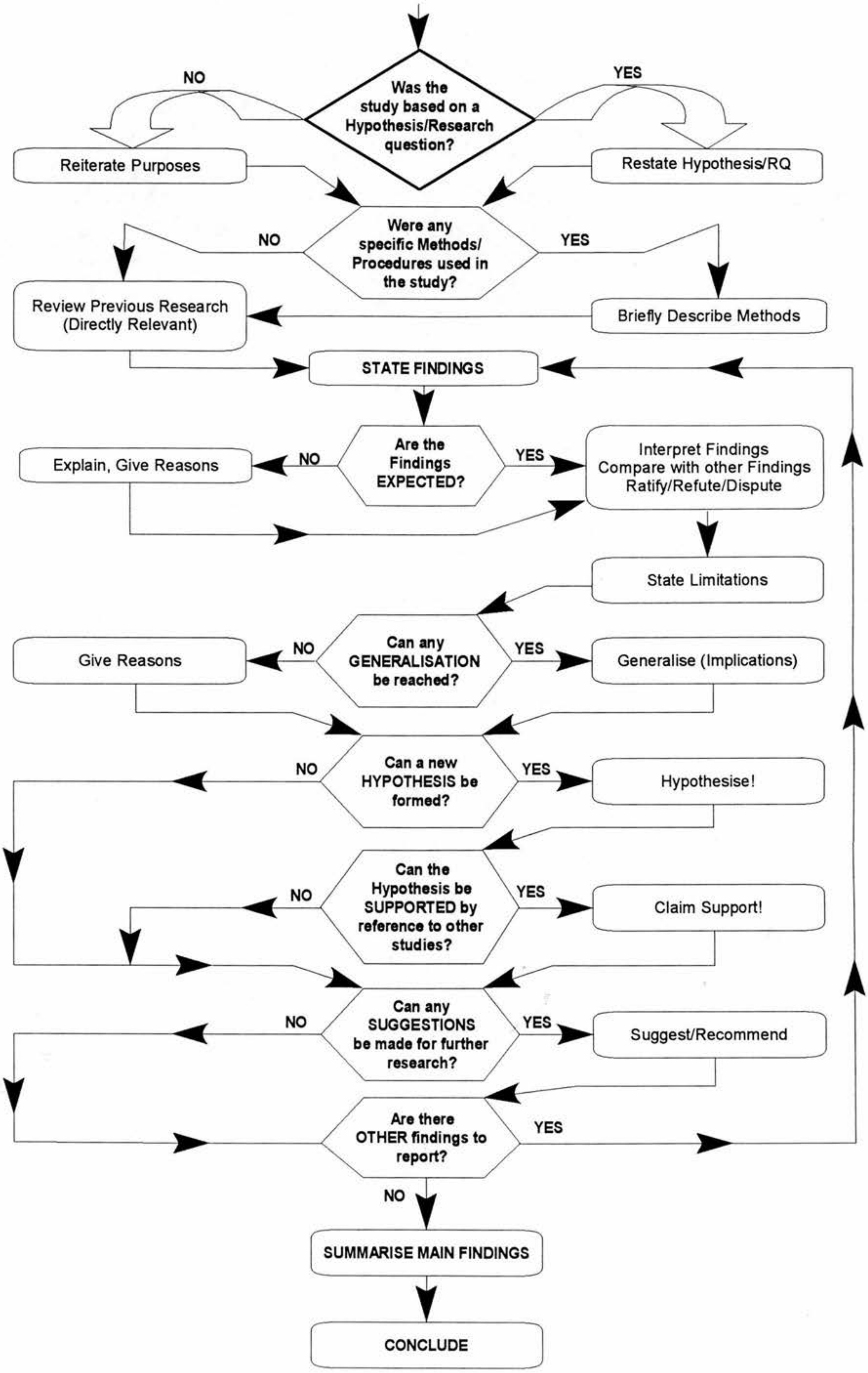

Figure 14: A Flowchart for Research Article Discussion

9.2.2.3 Sessions on Individual Moves

These sessions follow the same pattern as proposed for the introduction section: four sessions, one for each of the three Moves and a final consolidation session. Again, as the first three sessions are structured in a similar way, detailed breakdown of only the second, the most important and complex, session is provided as an example.

SESSIONS 8-10

Move 2: Discussing the Findings

1. ***Presentation:*** At the start of the session, a presentation is given about the purpose of Move 2 and the steps comprising Move 2, and their linguistic realisations.
2. ***Activity 9:*** The participants are given a number of Step 2.1 (*Reporting the Findings*), Step 2.2 (*Expanding on/Interpreting the Findings*), Step 2.3 (*Comparing/contrasting with previous Findings*), Step 2.4 (*Ratifying/refuting previous Findings*), and Step 2.5 (*Counter claiming, Question raising*) sentences from different discussions. They are asked to identify those sentences that realise the five steps and to group them so that each group makes a complete Move 2. Although with their specialist knowledge of the discipline, they should be able to group the Steps after they had identified them, examples will be kept simple (in terms of number of findings reported) and distinct (in terms of topic/subject), in order to minimise the possibility of their putting steps from different introductions together.
3. ***Discussion:*** The participants are encouraged to discuss their experiences, and to point out the problems they encountered during the task.
4. Sessions on the same pattern are arranged for the other moves.

9.2.2.4 The Cumulative & Follow-up Sessions

This session will take a somewhat different form from that proposed for the introduction section. It should be recalled that the discussion's having an explicit main conclusion or macroproposition depends to a large extent on whether or not the author has a clear focus, that is whether the author has clearly stated his purpose(s) in the introduction. Attempt will be made to make the participants aware of this fact.

SESSIONS 11-12

1. **Activity 10:** The participants are given three discussions (with explicit, implicit, and no macroproposition). They are asked to rate them on the basis of the final outcome of the research.
2. **Discussion:** The participants are asked to give reasons for their ratings.

3. **Activity 11:** As the absence of an explicit macroproposition can be traced to a lack of focus in the introduction, the participants are given the relevant introductions with the instructions to see the relation between an explicit macroproposition and a clear focus. They should be able to see for themselves the importance of the two and the relation between them.
4. **Presentation:** A brief presentation is given highlighting the importance of a clear focus, purpose, and a final explicit and well-presented macroproposition. The presentation is meant to emphasise that a clear focus comes from having to answer a research question or to solve a problem (put forward in the introduction), and that the explicitness of the main conclusion (arrived at in the discussion) depends on what the researcher wanted to achieve, in the first place, by asking the research question or by solving the problem.
5. **Follow-up:** The participants are encouraged to look closely at their published RAs and see whether they can find such a close relation between having a clear focus and drawing valid conclusions. They are asked to report back in another session whether they would like to revise any of their introductions or discussions or both. A follow-up session may be arranged for this purpose.

9.2.3 Sessions on Theme choice and Method of Development

9.2.3.1 Preamble

Although choosing one theme type most of the time and not choosing another is not really a problem, it does result in monotonous prose. The writer needs to vary his choice of theme type wherever it is expedient. The main thrust of the sessions is to apprise the scientists of the importance of interpersonal and textual themes as points of departure.

9.2.3.2 Sessions and Activities

SESSION 13

1. **Activity 12:** The participants are given several textual (structural) and interpersonal elements to match with several main clauses. As some textual elements may match with more than one clause, the objective of the activity is to make as many logical connections as possible even if it requires making minor changes to the clauses.
2. **Discussion:** The participants are encouraged to discuss their choices.
3. **Activity 13:** The participants are given several discourse elements to match with several main clauses. The rationale for this activity is the same as that for the preceding activity.
4. **Discussion:** The participants are invited to discuss their choices.
5. **Activity 14:** The participants are given several sentences with structural and discourse elements with the instructions to pick those which appear to have faulty logical connection.

6. **Discussion:** The participants are asked to give reasons for their selection.
7. **Presentation:** The presentation is intended to highlight the importance of logical connection between propositions and clauses. Emphasis is placed on the difference between clause elements and propositions of equal and unequal ranks and their subordination and coordination. Several examples are provided to explain every notion.

SESSION 14

1. **Activity 15:** The participants are given a paragraph with faulty method of development to discuss among themselves whether the paragraph has a consistent and coherent focus.
2. **Discussion:** The participants are given a modified version of the same paragraph to see whether or not they find it more readable. The participants are encouraged to discuss their views.
3. **Presentation:** The presentation is intended to highlight the importance of chaining topical themes for a consistent outlook on the topic under discussion.
4. **Activity 16:** The participants are given a few more paragraphs with faulty method of development to find out whether are now able to catch such errors.
5. **Discussion:** The participants are encouraged to discuss their experiences among themselves.

9.2.4 Sessions on Rhetorical Prosodies

9.2.4.1 Preamble

The strategy for this module remains the same: to help the participants see for themselves the difference that rhetorical prosodies can make to the impact of a text. Although the main areas of concern were found to be fewer textual elements, First Person pronouns, and greater use of modal expressions, it may be fruitful to pay attention to every category of rhetorical prosodies. However, here I will take up the ones which were found to be lacking in the Pakistani discussions. I have in mind three sessions to address the three principal problem areas.

9.2.4.2 Sessions and Activities

SESSION 15

1. **Activity 17:** The participants are given a passage stripped of metalinguistic comments. They are asked to decide whether the passage is easy or difficult to understand.
2. **Activity 18:** Whether they find it easy or difficult, they are given the same passage again with all the metalinguistic comments. They are asked to compare the two and

decide which one is easier to understand or interpret. They are also asked to determine what makes the second passage easier to grasp. As they will have both the passages, they will readily observe, I hope, that it was due to metalinguistic comments that the second passage was found easier. Time permitting, the activity may be repeated.

3. **Presentation:** A presentation highlighting the importance or desirability of signposting devices, such as metalinguistic comments, will be given.
4. **Discussion:** The participants are invited to share their views about signposting devices.
5. **Follow-up:** The participants are asked to look at their RAs and decide whether they would like to introduce metalinguistic comments, etc., at appropriate places in order to guide the reader. They are asked to report back their findings before the start of the next session.

SESSION 16

1. **Activity 19:** The participants are given examples (consisting of two or three sentences) with verbal, non-verbal and metaphorical modality. They are asked to give reasons for the authors' use of modality in each case.
2. **Presentation:** A presentation is given about mood and modality with emphasis on the relative certainty or tentativeness of each of the modal verbs and their non-verbal and metaphorical alternatives.
3. **Activity 20:** They are asked to look afresh at the examples and say whether any modality expression could be changed or altogether omitted.
4. **Discussion:** A discussion about the use and desirability of modal expressions is initiated in which the participants are urged to express their opinion about the use of modality.
5. **Follow-up:** The participants are asked to study their own research articles and decide whether they would keep the modality expressions or would prefer to make changes. They are asked to report back their findings before the start of the next session.

SESSIONS 17-18

The third session focuses on the use of First Person pronouns. As the use of First Person is closely linked with both the interpersonal and textual prosodies, this session also supplements and enhances the learning experiences of the preceding two sessions.

1. **Activity 21:** The participants receive several sentences beginning with *it*-projecting clauses (*It is suggested*, *It is inferred*) as well as sentences beginning with first person pronouns. They are asked, first, why the authors elected to use *we* or *I* in some cases and *it* in other cases. The objective of this activity is to find out whether they know about the difference that the use of *we* and *it* can make. With their specialist knowledge, they should be able to come up with their own reasons.
2. **Presentation:** A presentation is given about the use of first (and second) person pronouns as discussed in Chapter 7.

3. **Discussion:** A discussion is initiated about the desirability of first person (plural & singular) use in scientific articles. The discussion intends to find out whether or not they have any reservations about such use and whether they know about the 'inclusive' use of *we*.
4. **Follow-up:** Before concluding the session, they are asked to study their own research articles and see whether they would like to consider any changes in respect of person use. With their approval, a final, concluding, session may be arranged to discuss their findings.

It is hoped that such participatory and analytical work will help the participants become "more critical and more receptive readers of both their own work and of articles in journals" (Swales, 1984:84).

9.3 Supplementary Material

Of the several textbooks and advice books that claim to teach the non-native speaker of English how to become proficient in academic and scientific writing, none I found suited to the situation we are concerned with. The textbooks are aimed at students and novice writers with emphasis on writing good English whereas the advice books give nothing but advice, "splendid advice", as Swales (1984:79) puts it, "but hardly the stuff from which an EAP course can be directly fashioned." In fact, in practice, the majority of such advice is likely to be "more honored in the breach than in the observance" (Swales, 1987:55).

The only textbook that can supplement and provide further activities for the seminars and workshops proposed above is *Writing Up Research* by Weissberg and Buker (1990). Reviewing the book, Dudley-Evans (1991:250-51) writes: "[It] is an excellent example of a textbook that draws fully and effectively on the research carried out in this area [genre analysis] and translates it into a very successful set of materials that will be of great value to ESP teachers teaching academic writing." Dudley-Evans further praises the book for admirably meeting four criteria that he has always considered essential for a textbook that aims to teach non-native speakers to write articles, namely:

1. It should present a sufficient number of authentic examples of either whole articles or of the sections of articles to enable students, through guided questions, to develop an understanding of the conventions and structure of the whole article or the section of the article.

2. It should, through both inductive and deductive activities, teach the detailed structure and associated language of the various sections of the classic IMRD type of research report.
3. It should, in the context of a largely functional approach, deal with particular grammatical points, such as articles, tense choice in different sections, the use of active or passive, and the use of modals, that non-native speakers have been shown to have difficulty with.
4. It should include in each unit exercises that enable students to build up, as they progress through the book, a continuous piece of writing of their own that draws on the analyses and activities in the book.

However, he shows disappointment at the writers' devoting too much attention to the Introduction (three units) while paying less attention to the Discussion (one unit). This is in accord with his, as well as my, view that discussion is the most difficult section to write. The model proposed for the discussion section and the flowchart developed for teaching the genre structure of the RA discussion section will, I hope, remedy this deficiency.

Another book that I found of some value is called *Writing for a specific purpose* by Sandra McKay and Lisa Rosenthall (1980). According to the authors, the book is based on D.A. Wilkin's *Notional Syllabuses* (OUP, 1976). *Writing for a specific purpose* is neither concerned with the RA genre nor does it address the RA sections; however, the notions that the book covers, such as those of *inform/focus*, *assert/substantiate*, and *recommend*, *agree/disagree*, are relevant to the teaching of RA writing. These notion are the usual features of the research article. The last chapter is titled "The research paper", but the authors use it to refer to academic essays and projects that form part of a student's usual course-work rather than the scientific research paper intended for publication.

Their terms, *inform* and *focus*, refer to the writer's moving from general background information (Move 1 of the *CARS* model) to a statement of purpose (Move 3). These are the introductory functions of *informing* and *focusing*. *Assertion* and *substantiation* usually occur in the discussion sections. Assertions are general statements that give a broad idea about a specific topic. Assertions need to be substantiated by proofs which may come from the writer's own data and results, or data/results from other sources. If the data/results are limited, an assertion needs to be qualified in some way, for example by using modality. Such limitations lead to *recommendations* for future research which are again often tentative.

Similarly, McKay and Rosenthall use the term, *analyse* to refer to the close examination of available or suggested solutions to a problem or the findings reported by other scientists. This notion belongs both in the introduction and the discussion section. In the introduction section, such an analysis leads the writer to raise a question, indicate a gap/problem, or counter claim. In the discussion section, it may refer to the writer's comparing/contrasting his own findings with those of others in order to make a general claim or form a hypothesis. During such analyses, the writer may *agree* or *disagree* with previous workers. Depending on the writer's own findings, his agreement or disagreement may be strong or tentative. The writer then goes on to *generalise* and *predict*. These can be made with great certainty or with tentativeness depending on the support available for the same and on the strength of the writer's own conviction.

While the book by Weissberg and Buker can be directly used in the proposed sessions, the one by McKay and Rosenthall can be used only as a source of ideas and examples.

9.4 Conclusions

The aim of this chapter was to propose ways to address the problems identified in this study. As classroom teaching in this situation was ruled out, informal sessions consisting of seminars and workshops were found to be the only suitable means to achieve the objectives. The activities proposed in this chapter are only tentative; that is, they will need to be modified according to the actual time available and the time that the participants would be able to spare to attend the proposed series of seminars and workshops. It may also be possible to include other less problematic areas, such as the use of reporting verbs, tense, and voice.

In order to extend the scope of such seminars and workshops, it will be necessary to study Pakistani RAs from other science disciplines. This may point out other areas of concern which may or may not be specific to a certain discipline. Accordingly, a multi-faceted strategy will need to be adopted in order to avoid arranging separate seminars/workshops for each discipline.

Table 29 below (page 263) presents in outline form a comprehensive schedule for all the workshop sessions as proposed in this chapter. Objectives for each session and each activity are also provided.

9.5 Workshop Schedule and Objectives

TABLE 29: Proposal for Workshop Sessions on Professional Writing for Geologists

TOPIC	SESSION	FOCUS	OBJECTIVES	ACTIVITY
INTRODUCTION	1	**Genre**	1. To make the participants aware that the RA introduction has an underlying genre structure through doing genre analysis. 2. To familiarise the participants with the genre structure of the RA introduction. 3. To make them see the importance/utility of being aware of the genre structure of the RA introduction.	1 2 3
	2	**Move 1**	4. To familiarise the participants with the steps that comprise the opening Move.	4
	3	**Move 2**	5. To help the participants learn how to establish a niche. 6. To familiarise them with the different ways of establishing a niche (Counter-claiming; Indicating a gap/problem; Question-raising, etc.).	(4)
	4	**Move 3**	7. To familiarise the participants with the steps that comprise the closing Move (Move 3).	(4)
	5	**General Cumulative**	8. To consolidate the previous learning experiences. 9. To help the participants see the relative importance of the three Moves.	5
	6	**Follow-up**	10. To get feedback from the participants about their learning experiences during the preceding sessions. 11. To see whether they have been putting to good practice their newly acquired knowledge. 12. To learn whether all the objectives have been achieved.	--
DISCUSSION	7	**Genre**	1. To make the participants aware that the RA discussion has an underlying genre structure through doing genre analysis. 2. To familiarise the participants with the genre structure of the RA discussion section (flowchart). 3. To make them see the importance/utility of being aware of the genre structure of the RA discussion.	6 7 8
	8	**Move 1**	4. To familiarise the participants with the steps that comprise the opening Move.	(9)
	9	**Move 2**	5. To help the participants become aware of the steps involved in discussing the finding (through using the flowchart). 6. To help them see the importance of discussing the findings thoroughly.	9
	10	**Move 3**	7. To familiarise the participants with the steps that comprise the closing Move.	(9)
	11	**General Cumulative**	8. To consolidate previous learning experiences. 9. To help the participants see the relative importance of the three Moves. 10. To help them become aware of the fact that the discussion must have an explicit main conclusion, and that having such a main conclusion depends on a clear focus and purpose.	10 11
	12	**Follow-Up**	11. To get feedback from the participants about their learning experiences during the preceding sessions. 12. To see whether they have been putting to good practice their newly acquired knowledge. 13. To learn whether all the objectives have been achieved.	--

Table 29: Continued

TOPIC	SESSION	FOCUS	OBJECTIVES	ACTIVITY
THEME CHOICE	13	**Theme Choice**	1. To make the participants realise the importance of textual, discourse and interpersonal elements and expressions as points of departure for their propositions and claims. 2. To help them see the role of such points of departure in text coherence and cohesion.	12 13 14
	14	**Method of Development**	1. To help the participants realise that chaining of topical themes is important for a consistent focus on what is being discussed. 2. To make them understand the importance of chaining topical themes in their discussion.	15 16
RHETORICAL PROSODIES	15	**Textual Prosodies**	3. To make the participants aware of the effect that the use of comment prosodies (such as metalinguistic comments) can produce. 4. To encourage them to use such devices whenever appropriate. 5. To help them learn to be aware of the needs of their readers.	17 18
	16	**Interpersonal Prosodies**	6. To make them conscious of the meaning of modality. 7. To help them to become critical of the use of modality. 8. To make them aware that of the fact that overuse of modality makes things tentative (assertions v. qualified assertions).	19 20
	17	**Use of First Person**	9. To make the participants aware of the different uses of the first person plural (inclusive v. exclusive). 10. To make them conscious of the fact that using 'We' is sometimes more desirable than using the impersonal 'it'. 11. To help them see what difference the use of first person can make as against the use of 'it'. 12. To help them learn when to use and when not to use the first person (depending on whether they have very strong support for the assertion/statement and whether they are prepared to commit themselves to the truth value of the assertion).	21
	18	**Follow-UP**	13. To consolidate the learning experiences from the preceding sessions. 14 To learn whether or not the objectives have been achieved.	--

CHAPTER 10

Summary, Conclusions & Implications

10.0 Introduction

Working within the framework of genre analysis and systemic linguistics, this study was an attempt to examine published native and Pakistani geology experimental research articles (RAs) with a view to finding possible differences in the Pakistani geologists' scientific reporting *vis-à-vis* their native counterparts: differences in discourse organisation (genre), thematic choices (thematic configuration), the method of development, and the use of interpersonal (mood/modality, attitudinal adjuncts, etc.) and textual rhetoric (discourse adjuncts, metalinguistic comments, etc.). Also, a Three-Move rhetorical model was developed for the RA discussion section which was then used to compare the two datasets, each consisting of thirty research articles written by native and Pakistani academic geoscientists. Experimental RAs were used in the study for three very apparent reasons: (i) it is unquestionably the greatest exemplar of 'information exchange' in the world of science, bearing the full thrust of a discourse community's epistemic objectives; (ii) it has an established generic and discourse structure; and (iii) it has one globally acknowledged intention, that of persuading other scientists to consider and accept the truth and the worth of the author's research. All this makes the experimental RAs amenable to all kind of textual, discourse, and rhetorical analyses. In addition, using published RAs relieves the researcher of worrying about comparability problems which plague so much of the contrastive research. The theoretical frameworks used in the study proved not only productive but also illuminating. In fact, the framework of *rhetorical prosodies* (interpersonal & textual rhetoric) was unique to this study. In this respect, and in all other respects, the Pakistani RAs exhibited obvious and subtle differences. Following are the most important findings.

10.1 Summary of Findings

10.1.1 Genre and Rhetorical Organisation

10.1.1.1 The RA Introduction

The IMRD pattern was taken as a standard pattern for the experimental research article. A very high proportion of the Pakistani geology RAs did not conform to the IMRD pattern despite the fact that, like the RAs in the native dataset, they were all experimental papers. This can be interpreted as the Pakistani geoscientists' non-familiarity with the IMRD structure, an interpretation strengthened by the fact that the RAs in both the datasets deal with more or less similar topics: mineralogy, structure, metamorphic geology, petrology, etc.

For comparison of RA introductions, the *CARS* model (Swales, 1990) was used. A detailed Move/Step analysis of the sixty introductions revealed that the three Swalesian Moves were found to be a regular feature of the geology introduction; however, the geology introduction had some features which were not accounted for by the *CARS* model. It was expected as geology appears to be one of those disciplines which has not been hitherto used in such studies. The features which were not accounted for by the model — background information and reference to method/procedure — were found in both the native and the Pakistani RA introductions; as such, changes to this effect were proposed and incorporated in the model.

The concept of front-shifting, back-shifting, and repeat steps was used in order to compare the introductions from the two datasets. Front-shifting referred to the occurrence of a step earlier than its assigned position in the *CARS* model. Front-shifting displaces another step which then occurs later than its assigned position in the model. Steps are often repeated which gives rise to cyclicity. This concept proved useful as it provided fresh insights into a writer's rhetorical choices. For example, there was a good deal more Move 2 (*Establishing a niche*) front-shifting in the native introductions whereas there was more front-shifting of the purposive step (Step 3.1) in the Pakistani introductions. Thus, it appears that the Pakistani authors, instead of establishing a niche, tended to announce their purposes quite soon. Again, there was more front-shifting and less repetition of Step 1.3 (*literature review*) in the Pakistani introductions than in the native ones.

A very important finding was the absence of the crucial Move 2 from as many as ten Pakistani introductions, and its delayed occurrence in as many as four introductions. This move is concerned with *Establishing a niche* which the writer proposes to fill with his research. As such, its absence may reflect not only on the writer's purpose but also on the legitimacy of the entire research venture. It appears that the Pakistani geologists did not pay heed to situating their research in terms of its significance in the field as a whole. Moreover, the native geologists tended to establish a research niche quite earlier in the introduction (even before the literature review step: 10 examples) while their Pakistani counterparts appeared to delay it very late in the introduction (only two had a Move 2 before the literature review). Only eleven Pakistani and seventeen native introductions had the Move 2 in the assigned position. However, while as many as eight Pakistani introductions had it delayed considerably, only one NS introduction had it delayed to a comparable extent (NS-28).

Another point of note was that Move 2 in the Pakistani introductions were mostly of the type of *indicating a gap* and *continuing a tradition* while in the NSE introductions, they were of the type of *indicating a gap* and *counter claiming*. One instance of *question raising* type Move 2 was also found in the NSE introductions.

Move 3 (*Occupying the niche*) was found to be a regular feature of introductions from both the samples, and Step 3.1b (*Announcing present research*), noted in 20 NS and 20 PAK introductions, was the favoured choice. Step 3.2, *announcing principal findings*, was a rare feature, found only in three NS and six PAK introductions. Again, Step 3.3, *indicating structure of RA*, was found only in three NS introductions (NS-04; NS-28; NS-29). Moreover, no Step 3.3 (*Indicating Structure of RA*) was found in the Pakistani introductions while only two NS introductions had this step.

Another important finding related to the length of the three moves in the two datasets. It was found that whereas Move 2 in the Pakistani introductions was much shorter, Move 1, the introductory move, was much longer. These differences were found statistically significant. It would, therefore, appear that the Pakistani geologists did not consider Move 2 to be very important. They seemed to be content with announcing their purposes only. The absence of this move in several introductions also points to this conclusion. The native referees' comments, as discussed in Chapter 8, suggest that this is generally true of Pakistani RA introductions. For example, one referee asked the writer to "define more precisely what the paper aims to do" whereas another referee commented that "The intention of the second paragraph is unclear and should be reformulated."

10.1.1.2 The RA Discussion

In order to compare the discussion sections of the RAs in the two datasets, first, a 3-Move model, on the pattern of the *CARS* model, was proposed. Next, making it the basis of comparison, the native and the Pakistani discussions were compared on several accounts, qualitative and quantitative.

The first move of the model, (*Re-setting the perspective*), deals with providing a kind of introduction before plunging into a discussion of the findings. This was found to be the usual opening move. It was found to be a reflection of the introduction, in which the writer sometimes described his methods, procedures, techniques, and data, and usually briefly referred to the most relevant previous research.

Being concerned with *discussing the findings*, Move 2 forms the core of the discussion section. It was, therefore, found to be very cyclical. As for the steps, Steps 2.1 and 2.2 (*Reporting the findings, and Interpreting the findings*) either occurred in quick succession or simultaneously. It depended on the number of results and how the writer elected to report and interpret them.

Move 3 (*Generalising the findings*) marks the end of the discussion section. Of the three steps that comprise this Move, Step 3.1 (*Making a general claim/hypothesis*) may be considered the obligatory step. This step is usually followed by *claiming* *support for the claim/hypothesis*. These two steps, therefore, occur in juxtaposition or quick succession.

In comparison with the introduction section, the rhetorical organisation of the discussion section seems more varied. It is already well documented in the literature that the discussion section has a less predictable structure than the introduction (Dudley-Evans, 1986; Jingfu, 1987; Hopkins and Dudley-Evans, 1988; Dubois, 1989). It, therefore, makes it difficult to comment on the differences between the native and the Pakistani discussions. However, it was possible to compare the native and the Pakistani discussions in two ways: one quantitative and one qualitative. Quantitatively, the lengths of individual moves would determine the relative importance that the moves receive from the two categories of scientists. And qualitatively, one could look at the end result of the discussion: (a) whether the conclusions drawn are clearly stated, vaguely stated, or not stated at all; and (b) whether they are presented as one discourse act at the end, a final cumulative proposition of the total research venture, a kind of *macroproposition*, or stated disjointedly at different places.

In terms of relative lengths of the three moves, Move 2 stands out as the most prominent, being the nucleus of the section. However, whereas in the native discussions, Move 2 was significantly longer than the other two moves, it had the same length as Move 1 in the Pakistani discussions. This shows that the Pakistani geologists wrote longer opening moves. This is consistent with what Scarcella (1984) found in his comparative study of orientations employed by native and non-native writers in expository essays. His non-native writers wrote longer orientations than the native writers. The Pakistani writers also wrote shorter Moves 2 & 3. It would, therefore, appear that the Pakistani geologists do not discuss and interpret their findings at length, and that they do not often generalise, hypothesise, make a claim, or draw a conclusion on the basis of their findings.

A comparison of the native and the Pakistani discussions on qualitative basis also revealed that the latter did not present a *macroproposition*. If we view the introduction as the section wherein the researcher asks questions, the discussion becomes the section wherein those questions are answered. By asking questions, and by pointing out problems in the introduction, the researcher becomes obliged to answer those questions and solve those problems, or propose possible answers and possible solutions in the discussion. It follows that the strength of the discussion section lies not only in explicitly answering the research questions but also in *fully* answering *all* the questions. And if a question remains unanswered, reasons should be provided along with recommendation for future research. The Pakistani discussions were found to be weak on this account. Remembering that several Pakistani introductions did not have a Move 2 (the move concerned with asking questions, indicating problems etc.), it is quite understandable why several Pakistani discussions did not have an explicit *macroproposition*. This would appear to be a problem with non-native scientist writers. For example, twenty-eight percent of Gosden's (1992) respondents (journal editors) commented that the main problem with NNS scientists was not paying much attention to discussing their results clearly, logically, and adequately. The Pakistani geologists have the same problem. This has clear implications for such RA manuscripts being sent for publication in international journals. For example, one manuscript had the following comment from the native referee: "I think that the paper would benefit from a more detailed discussion of *how you arrive at your interpretation"*. Here is another comment: "As it stands, there is no mention of element mobility and until this is fully addressed much of what has been discussed in the paper is dubious to say the least."

10.1.2 Systemic Text Analysis

10.1.2.1 Theme Choice and Method of Development

This was the concern of Chapter 6. From this study, we learnt that the Pakistani writers used fewer interpersonal points of departure for their messages; in other words, they did not foreground their own personal view or angle as much of the time as their native counterparts. The Pakistani geologists also did not thematise structural elements to signal local cohesion, though they used enough discourse adjuncts to establish coherence. It was also found that the Pakistani geologists used postponed themes not only more than expected but also more than the native geologists. More postponed themes means more *It* constructions of the *It is suggested/proposed/ argued* type which is the sign of not only impersonality but also lack of confidence in one's findings and one's evidence and lack of commitment to the truth of one's assertions and propositions. We can, therefore, conclude that the Pakistani RA discussions would be less effective in terms of achieving the purpose for which they are written.

Another concern of Chapter 6 was the method of development of Pakistani paragraphs. Two paragraphs were analysed which revealed that the Pakistani geologists had problems with chaining topical themes which is important for maintaining a consistent focus on the topic under discussion. A revision of the paragraphs revealed that perhaps the writers were not very clear about what they were trying to communicate. No such problems were discovered in the discussions from the native RAs. Since we have been able to find problems with such short paragraphs, we can conclude that, in longer paragraphs, we would encounter, *a fortiori*, many more such problems.

10.1.2.2 Rhetorical Prosodies

The term *rhetorical prosodies* was coined in order to cover interpersonal and textual rhetoric. Rhetorical prosodies, as used and understood in this study, are the linguistic means which experienced writers use to attend to the needs of the readers, the demands of the discourse, and the norms and conventions of the genre. Whereas interpersonal rhetoric is concerned with how writers attend and respond to the relationship that obtains between them and their readership, textual rhetoric pertains to how writers develop their arguments in keeping with the norms and conventions of the discourse and the genre. This was an interesting study, and brought to light some of the unexplored facets of contrastive rhetorical analysis.

Main differences were observed in the use of interpersonal rhetoric. Whereas the native geologists used more modal verbs, more attitudinal/evaluative prosodies, and more First Person pronouns, the Pakistani geologists used more modal expressions (hedges). This is inconsistent with the general impression that non-native writers usually make sweeping and indiscreet generalisations. The Pakistani geologists appear to be more cautious, and hence more tentative in their conclusions and claims. In addition, extremely sparse use of the First person pronoun by the Pakistani geologists may be interpreted as their lack of confidence in their findings and evidence or lack of preparedness to commit themselves to the truth value of their assertions. Extreme tentativeness most of the time tends to cast doubt on the validity of the research itself.

As the choice of an initial textual prosody constrains the selection of lexis, tense, and voice in the ensuing clauses, Pakistani geologists were found to have problems with logical connectives and some discourse adjuncts which resulted in clumsy and awkward constructions. A number of examples were discussed with suggestions for improvement.

10.2 Conclusions and Implications

The implications of the findings summarised above are both general and specific. In general terms, the findings have implications for the kind of contrastive text analysis that deals with two groups of subjects with two different language backgrounds, and two groups of texts, one comprising texts written in English as L1, and the other consisting of texts written in English as L2. As far as my knowledge goes, no study hitherto has attempted to do a contrastive analysis of this kind in terms of the frameworks adopted in this study: interpersonal and textual themes as points of departure, rhetorical prosodies, and genre analysis. Again, to my knowledge, no study exists that uses systemic linguistics as a model for comparative/contrastive textual analysis. That the findings were meaningful, illuminating and insightful point to the potential that the systemic approach holds for contrastive/comparative text analysis.

In specific terms, every finding has its own theoretical, practical, and pedagogical implications. What follows is a list of the major conclusions along with their implications:

1. That the geology RA introduction (hitherto neglected) had the three Swalesian moves strengthens the view that the 3-Move rhetorical organisation of RA

introductions is entrenched in the way science is done, and that it is not specific to this or that discipline. This calls for treating the RA introduction as a prototype. This would relieve the ESP/EAP practitioner of worrying about discipline specific rhetorical organisation.

2. That the Pakistani RA introduction was deficient in certain respects as well as different from the native RA introduction (longer Move 1, missing/delayed or obscure Move 2, and vague Move 3) may be ascribed to the Pakistani scientists' unfamiliarity with the rhetorical demands of the introductions section. They must, therefore, be made aware of the rhetorical organisation of the RA introduction and the relative importance of the three moves.

3. That both the native and the Pakistani discussion sections had the three moves as described in this study suggest that the rhetorical organisation of the RA discussion section may also be prototypical. In the discussion section, the writer needs to discuss, interpret, and debate his findings with respect to others' findings, hypothesise or make claims on their basis, and generalise and draw conclusions. This is the prototypical rhetoric of all science.

4. That the Pakistani discussions had a longer Move 1, a shorter Move 2, and a shorter Move 3 point to a sketchy treatment of the findings. To have the desired impact, the findings must be discussed from every possible angle. In any course on research writing, the importance of discussing one's results and findings adequately must be stressed time and again.

5. That several Pakistani discussion sections did not have an identifiable terminal, cumulative proposition indicates that the Pakistani geologists probably did not have a clear purpose, usually signalled by Move 2 and Move 3 in the introduction section. It may be recalled that the Pakistani introductions were weak on this account, too. The non-native scientists must be told that every experimental research should have an explicitly stated outcome even if the conclusion itself is not clear.

6. That the Pakistani RA discussions had fewer than expected interpersonal expressions as points of departure for their propositions and statements points to a

possible interplay of cultural and linguistic norms and values. This calls for a contrastive analysis of experimental research articles published in other languages along the same lines and parameters. This will help in determining whether the differences are cultural, linguistic, or developmental.

7. That the Pakistani RA discussions had fewer than expected textual points of departure indicates that the Pakistani geologists did not use adequate signals to indicate local cohesion. The Pakistani discussions were, therefore, expected to be lacking in cohesion. In fact, problems were found with the method of development of two very short paragraphs. This calls for explicitly teaching the method of development for topic chaining.

8. That the Pakistani discussions had more modal expressions and very sparse First person pronouns suggest over-tentativeness and non-commitment on the part of the writers. This may make the reported research lose its credibility and merit. It is, therefore, imperative that the non-native scientists be made aware of this important caveat.

10.3 Limitations & Recommendations

Every endeavour, however ambitious, has its limitations. This fundamental truth is beautifully captured in the lines from *Andrea del Sarto* by Robert Browning which I have quoted in the beginning of the thesis. The quote professes that this study is not without limitations though it has achieved the purpose for which it was undertaken.

Undertaken with the sole purpose of finding out how different the Pakistani geology research articles were from those written by native geologists, this study adopted an eclectic approach to account for the several aspects which accompany writing in a second language and doing science, and which ultimately show up in the reports. Although I made an all out effort to utilise the resources of the approaches to the full, it was not always possible. Restraint, caution, and discrimination needed to be exercised in deciding what to do and what not to do; that is, to determine whether an analysis would reveal something only insightful or both insightful and meaningful. Such decision-making was made possible by the concept of the discourse community, the background of the writers, and the purpose and intention of the reports. Still, it is possible to extend the scope of this study in several directions. A few directions for further research are suggested below.

1. A comparative/contrastive study of Pakistani and native RAs in other disciplines to determine whether the problems and deficiencies identified in this study are discipline-specific or whether they are common to all disciplines.

2. A three-pronged comparative/contrastive study of Pakistani research articles (in any discipline) published indigenously in English and in Urdu, and published in international journals to determine the exact sources of the problems and deficiencies.[1]

3. An application of Systemic linguistics to Urdu discourse to determine whether the problems and shortcomings identified in the Pakistani RAs are due to linguistic background.

4. A study of the politeness principles in Pakistani culture to understand the non-assertive and generally impersonal behaviour of the Pakistani geologists.

5. A national survey to elicit comments from Pakistani scientists about their own perceived problems when writing in English, particularly when intending to send their manuscripts abroad for international publication.

6. Design and implementation of workshops and seminars on research writing for Pakistani scientists. Some suggestions have already been made in Chapter 9 in this regard.◆

---

[1] In fact, in the beginning, I had this kind of study in mind. However, the data I collected were too small to be of any use. It was very rare to find a Pakistani research article published in international journals without a native co-author. And scientific publications in Urdu are unheard of.

References

Adams-Smith, D. E. (1984). Medical discourse: Aspects of authors' comments. *ESP Journal*, 3:25-36.

Adams-Smith, D. E. (1987). Variation in field-related genres. *ELR Journal*, pp. 10-32.

Ard, J. (1982). The semantics of tense and aspect in scientific discourse. Paper given at Ohio State University Conference on the Semantics of Tense and Aspect, May, 1982.

Ard, J. (1985). Vantage points for the analysis of scientific discourse. *English for Specific Purposes*, 4:3-20.

Ballard, B. and Clancy, J, (1988). Literacy in the university: an anthropological approach. In Taylor, G. et al. *Literacy by Degrees*. Milton Keynes: Open University Press.

Barber, C.L. (1962). Some measurable characteristics of modern scientific prose. In *Contributions to English syntax and phonology*. Stockholm: Almquist and Wiksell.

Bartlett, F.C. (1932). *Remembering*. London: Cambridge University Press.

Basham, C.S. and Kawachka, P.B. (1991). Reading the world differently: A cross-cultural approach to writing assessment. In Hamp-Lyons, L. (ed) *Second language writing in academic context*. Norwood, NJ.: Ablex. pp. 37-49.

Bazerman, C. (1988). *Shaping Written Knowledge*. Wisconsin: University of Wisconsin Press.

Becher, T. (1987). Disciplinary discourse. *Studies in Higher Education*, 12(3):261-74.

Belanger, M. (1982). *A preliminary analysis of the structure of the discussion sections in ten neuroscience journal articles* (mimeo). As reported by Swales (1990).

Ben-Amos, Dan (1976). Introduction. In Ben-Amos, D. (ed.). *Folklore Genres*, (ix-xv). Austin: University of Texas Press.

Benson, J. D. and Greaves, W. S. (eds.) (1985a). *Systemic Perspectives on discourse Vol 1: Selected theoretical papers from the 9th International Systemic Workshop*. New Jersey: Ablex Publishing Corporation.

Benson, J. D. and Greaves, W. S. (eds.) (1985b). *Systemic Perspectives on discourse Vol 2: Selected theoretical papers from the 9th International Systemic Workshop*. New Jersey: Ablex Publishing Corporation.

Bhatia, V. K. (1991). A genre-based approach to ESP materials. *World Englishes*, 10(2):153-66.

Bhatia, V. K. (1993). *Analysing genre: Language use in professional settings*. London: Longman.

Billig, M. (1987). *Arguing and thinking: a rhetorical approach to social psychology*. Cambridge: Cambridge University Press.

Black, E. (1978). *Rhetorical criticism: A study in method*. Madison: University of Wisconsin Press.

Blanchot, M. (1982). *The space of literature*. Lincoln: University of Nebraska Press.

Bley-Vroman, R. and Selinker, L. (1984). Research design in rhetorical/grammatical studies: A proposed optimal research strategy. *ESP Newsletter*, 82-83:1-4; 84:1-6.

Braddock, R. (1974). The frequency and placement of topic sentences in expository prose. *Research in the Teaching of English*, 8:287-302.

Brandt, D. (1986). Text and context: how writers come to mean. In Couture, B. (ed.). pp. 91-107.

Brandt, D. (1992). The cognitive as social: An ethnomethodological approach to writing process research. *Written Communication*, 9(3):315-55.

Brown G. and Yule, G. (1983). *Discourse Analysis*. Cambridge: CUP.

Brown, P. and Levinson, S.C. (1987). *Politeness: some universals in language usage*. Cambridge: CUP.

Bruce, N. J. (1983). Rhetorical constraints on information structure in medical research report writing. Paper presented at the *ESP in the Arab World Conference*, University of Aston, U.K., August, 1983. (As reported by Swales 1990.)

Butler, C. S. (1990). Qualifications in science: modal meanings in scientific texts. In Nash, Walter (ed.):137-70.

Cairns, Francis (1972). *Generic composition in Greek and Roman poetry*. Edinburgh.

Calnan, J., and Barabas, A. (1973). *Writing medical papers: a practical guide*. London: Hienemann.

Campbell, K.K. (1973). The rhetoric of women's liberation: an Oxymoron. *Quarterly Journal of Speech*, 59:74-86. As cited in Miller (1984).

Campbell, K.K. and Jamieson, K.H. (eds.). (1978). *Form and genre: shaping rhetorical action*. Falls Church, VA: Speech Communication Association.

Candlin, C.N., Kirkwood, J.M., and Moore, H.M. (1978). Study skills in English: Theoretical issues and practical problems. In Mackay, R., and Mountford, A. (eds), 190-219.

Carrell, P. L. (1983). Some issues in studying the role of schemata, or background knowledge in second language comprehension. *Reading in a Foreign Language*, 1(2):87-112.

Carrell, P. L. (1984a). Evidence of a formal schema in second language comprehension. *Language Learning*, 34(2):87-112.

Carrell, P. L. (1984b). The effects of rhetorical organization on ESL readers. *TESOL Quarterly*, 18(3):441-69.

Carrell, P. L. (1987). Content and formal schemata in ESL reading. *TESOL Quarterly*, 21(3):461-81.

Chafe, W.L. (1976). Givenness, contrastiveness, definiteness, subjects, topics and points of view. In Li, C.N. (ed). *Subject and Topic*. New York: Academic Press.

Chafe, W. and Nichols, J. (eds) (1986a). *Evidentiality: The linguistic coding of epistemology*. Norwood, NJ.: Ablex.

Chomsky, N. (1971). Deep structure, surface structure, and semantic interpretation. In Steinberg, D. and Jakobvit, L. (eds). *Semantics: An interdisciplinary reader in philosophy, linguistics, and psychology*. NY: Cambridge University Press (pp. 183-216).

Clyne, M.G. (1987). Cultural differences in the organization of academic texts. *Journal of Pragmatics*, 11:211-47.

Coates, J. (1983). *The semantics of the modal auxiliaries*. Beckenham, England: Croom Helm.

Coates, J. (1987). Epistemic modality and spoken discourse. *Transactions of the Philological Society 1987*, 110-131.

Colie, Rosalie (1973). *The resources of kind: Genre-theory in the Renaissance*. Berkley: University of California Press. (Edited by Barbara K. Lewalski.)

Collins, A. and Gentner, D. (1980). A framework for a cognitive theory of writing. In Gregg and Steinberg (eds.).

Connor, U. and Kaplan, R.B. (eds) (1987). *Writing across languages: Analysis of L2 text*. Reading, Mass.: Addison Welsley.

Conte, M.E., Petöfi, J. and Sözer, E. (eds) (1989). *Text and discourse connectedness*. Amsterdam: John Benjamin (53-63).

Cooper, C. (1985). Aspects of article introduction in IEEE publications. Unpublished M.Sc. dissertation, University of Aston, U.K.

Cooper, C. and Greenbaum, S. (eds), (1986). *Studying writing: Linguistic approaches*. Beverly Hills: Sage.

Cope, B. and Kalantzis, M. (1993). Introduction· How a genre approach to literacy can transform the way writing is taught. In Cope, B. and Kalantzis, M. (eds) (pp. 1-21).

Cope, B., and Kalantzis, M. (eds) (1993). *The powers of literacy: A genre approach to teaching writing*. London: The Falmer Press.

Corbett, E.P.J. (1981). A rhetorician looks at technical communication. In Mathes, J.C. & Pinelli, T.E. (eds.). *Technical communication: Perspective for the eightees.* Washington, DC: National Aeronautics and Space Administration.

Coulthard, M. (1994). *Advances in written text analysis*. London: Routledge.

Couture, B. (1985). A systemic network for analyzing writing quality. In Benson, J.D. and Greaves, W.S. (eds). (1985b), pp. 67-87.

Couture, B. (1986). Effective ideation in written text: A functional approach to clarity and exigence. In Couture, B. (ed.), pp. 62-92.

Couture, B. (ed) (1986). *Functional approaches to writing: research perspectives*. Norwood, NJ: Ablex.

Crismore, A. and Farnsworth, R. (1990). Metadiscourse in popular and professional discourse. In Nash, W. (ed).

Crismore, A. and Vande Kopple, W.J. (1988). Readers learning from prose: The effects of hedges. *Written Communication*, 5(2):184:202.

Crismore, A., Markkanen, R. and Steffenson, M.S. (1993). Metadiscourse in persuasive writing: A study of texts written by American and Finnish university students. *Written Communication*, 10(1):39-71.

Crookes, G. (1986). Towards a validated analysis of scientific text structure. *Applied Linguistics*, 7:57-70.

Danes, F. (1964). A three-level approach to syntax. *Travaux Linguistique de Prague*, 1:225-240.

Danes, F. (1970). One isntance of prague school methodology: Functional analysis of utterance and text. In Garvin, P.L. (ed), *Method and theory in linguistics*. The Hague: Mouton.

Danes, F. (1974). Functional sentence perspective and the organization of the text. In Danes, F. (ed), *Papers in functional sentence perspective*. Prague: Academia.

Davies, F. (1988). Reading between the lines: Thematic choice as a device for presenting writer viewpoint in academic discourse. *The ESPecialist*, 9(1/2):173-200.

Davis, R.M. (1985). Publication in professional journals: A survey of editors. *IEEE Transactions of Professional Communication PC*. 28(2):34-42.

Day, R. (1979). *How to write and publish a scientific paper*. Cambridge: Cambridge University Press.

Dillon, G.L. (191). *Contending rhetoric: Writing in academic disciplines*. Bloomington, IN: Indiana University Press.

Doushaq, M. H. (1986). An investigation into the stylistic errors of Arab students learning English for academic purposes. *English for Specific Purposes*, 5(1):27-39.

Downing, A. (1991). An alternative approach to theme: A systemic-functional perspective. *Word*, 42(2):119-143.

Dubois, B.L. (1987). A reformulation of thematic progression typology. *Text*, 7(2):89-116.

Dudley-Evans, T. (1986). Genre analysis: An investigation of the introduction and discussion sections of MSc dissertations. In Coulthard, M. (ed), *Talking about text*. Discourse Analysis Monograph No. 13. ELR, University of Birmingham.

Dudley-Evans, T. (1991). Reviewing *Writing Up Research*. *English for Specific Purposes*. 10:250-52.

Dudley-Evans, T. (1994). Genre analysis: An approach to text analysis for ESP. In Coulthard, M (ed). pp. 219-228.

Dudley-Evans, T. and Henderson, W. (1990). The organization of article introductions: Evidence of change in economics writing. *ELT Documents*, 134:67-78.

Een, J. A. (1982). Tense usage in reporting research in geotechnical writing. *Working Papers in ESL (2)*, 72-91. Minneapolis: University of Minnesota.

Eggington, W.G. (1987). Written academic discourse in Korean: Implication for effective communication. In Connor, U. and Kaplan, R.B. (eds). pp. 153-68.

Eiler, M. (1986). Thematic distribution as a heuristic for written 2discourse function. In Couture, B. (ed), pp. 49-68.

Ellis, J. (1987). The logical and textual functions. In Halliday and Fawcett (eds.). pp. 105-129.

Fahnestock, J. (1986). Accommodating science: The rhetorical life of scientific facts. *Written Communication*, 3(3):275-96.

Fawcett, R.P. and Young, D. (eds) (1988). *New developments in systemic linguistics: Theoy and application*. London: Pinter Publishers.

Firbas, J. (1964). On defining the theme in functional sentence analysis. *Travaux Linguistique de Prague*, 1:267-280.

Flower, L. and Hayes, J. R. (1980). The dynamics of composing: making plans and juggling constraints. In Gregg and Steinberg (eds.).

Fowler, A. (1982). *Kinds of literature: an introduction to the theory of genres and modes*. Oxford: Clarendon.

Fowler, R. and Kress, G. (1979). Critical linguistics. In Fowler, R., Hodge, B., Kress, G., and Trew, T. (eds), *Languagae and control*. London: Routledge and Kegan Paul.

Francis, G. (1986). *Anaphoric nouns*. Birmingham: English Language Research, University of Birmingham.

Francis, G. (1994). Labelling discourse: An aspect of nominal group lexical cohesion. In Coulthard, M. (ed), pp. 83-101.

Frankenberg-Garcia, A. (1990a). Second language writing instruction. Unpublished PhD Thesis, University of Edinburgh.

Frankenberg-Garcia, A. (1990b). Do the similarities between L1 and L2 writing process conceal important differences? *Edinburgh Working Papers in App. Linguistics*, 1:91-102.

Freed, R.C. and Broadhead, G.J. (1987). Discourse communities, sacred texts, and institutional norms. *College Composition and Communication*, 38:154-65.

Fries, P. (1981). On the status of theme in English: Arguments from discourse. *Forum Linguisticum*, 6(1):1-38. Also in Petöfi, J.S. and Sözer, E. (eds) (1983). pp. 116-152.

Fries, P. (1983). Micro and macro connexity of text. In Petöfi, J.S. and Sözer, E. (eds).

Frye, N. (1957). *Anatomy of Criticism*. Princeton, NJ.: Princeton University Press.

Gage, J.T. (1986). Why write? In Petrosky, A.R. and Bartholomae, D. (eds), *The Teaching of Writing*. Chicago, Illinois: The University of Illinois Press.

Ghadessy, M. (ed) (1988a). *Registers of written English*. London: Pinter Publishers.

Ghadessy, M. (ed) (1988b). *Written language: Register and style*. London: Pinter.

Gilbert, G. N. and Mulkay, M. (1984). *Opening Pandora's box: a sociological analysis of scientific discourse*. Cambridge: Cambridge University Press.

Giora, R. (1983). Segmentation and segment cohesion: On the thematic organization of text. *Text*, 3(2):155-81.

Gopnik, M. (1972). *Linguistic structures in scientific texts*. The Hague: Mouton.

Gosden, H. (1992a). Discourse function of marked theme in scientific research articles. *English for Specific Purposes*, 11:207-224.

Gosden, H. (1992b). Research writing and NNSs: From the editors. *Journal of Second Language Writing*, 1(2):123-39.

Grabe, W.P. (1987). Contrastive rhetoric and text-type research. In Connor, U. and Kaplan, R.B. (eds). pp. 115-37.

Graetz, Naomi. (1985). Teaching EFL students to extract structural information from abstracts. In Ulijin, J.M. & Pugh, A.K. (eds.). *Reading for professional purposes*. Leuven, Belgium: ACCO.

Gregg, L. and Steinberg, E. (eds) (1980). *Cognitive processes in writing*. Hillside, NJ: Lawrence Erlbaum.

Gregory, M. (1967). Aspects of varieties differentiation. *Journal of Linguistics*, 3.

Gregory, M. (1985). Towards `communication' linguistics: a framework. In Benson and Greaves (eds.) (1985a). 119-134.

Gregory, M. and Carrel, S. (1978). *Language and situation: Language varieties in their social contexts*. London: Routledge and Kegan Paul.

Gronbeck, B. (1978). Celluloid rhetoric: on genres of democracy. In Campbell and Jamieson (eds.). 139-61.

Gunawardena, C.N. (1989). The present perfect in the rhetorical division of biology and biochemistry journal articles. *English for Specific Purposes*, 8:265-75.

Halliday, M.A.K. (1964). Descriptive linguistics in literary studies. In McIntosh A. and Halliday, M.A.K. (eds.) (1966). 56-69.

Halliday, M.A.K. (1964/76). English system networks. In Kress, G.R. (ed) (1976). *Halliday: System and function in language*. London: Oxford University Press. (101-35).

Halliday, M.A.K. (1967). Notes on transitivity and theme in English, (Part 2). *Journal of Linguistics*, 3:177-274.

Halliday, M.A.K. (1970). Functional diversity in language as seen from a consideration of modality and mood in English. *Foundations of Language*, 6:322-61.

Halliday, M.A.K. (1973). *Explorations in the functions of language*. London: Edward Arnold.

Halliday, M.A.K. (1974). *Language and social man*. London: Longman.

Halliday, M.A.K. (1976). English system networks. In Kress, G. R. (ed.). *Halliday: system and function in language*, 101- 35. London: OUP.

Halliday, M.A.K. (1977). Text as semantic choice in in social contexts. In van Dijk, T.A., and Petöfi, J. (eds), *Grammars and descriptions*. Berlin: Walter de Gruyter.

Halliday, M.A.K. (1978) *Language as social semiotics: the social interpretation of language and meaning*. London: Edward Arnold.

Halliday, M.A.K. (1985a). *An introduction to functional grammar*. London: Edward Arnold.

Halliday, M.A.K. (1985b). *Spoken and written language*. Geelong, Vic.: Deakin University Press.

Halliday, M.A.K. (1989). Part A. In Halliday and Hasan, (3-49).

Halliday, M.A.K. (1990). Some grammatical problems in scientific English. *Australian Review of Applied Linguistics*, 5(6):13-17.

Halliday, M.A.K. (1993). The analysis of scientific texts in English and Chinese. In Halliday and Martin (1993c), pp. 124-32. (Originally presented at the International Conference on Research in Texts and Language, Xi'ang Jiaotong University, March 1989.)

Halliday, M.A.K. (1994). *An introduction to functional grammar.* London: Edward Arnold. (2nd Ed.).

Halliday, M.A.K., and Fawcett, R.P. (1987). *New developments in systemic linguistics: Theory and description.* London: Pinter Publishers.

Halliday, M.A.K. and Hasan, R. (1976). *Cohesion in English.* London: Longman.

Halliday, M.A.K., and Hasan, R. (1989). *Language, context, and text: aspects of language in a social-semiotic perspective.* Oxford: OUP.

Halliday, M.A.K., and Martin, J.R. 1993a). The [systemic] model. In Halliday and Martin (1993c), pp. 22-50.

Halliday, M.A.K., and Martin, J.R. (1993b). General Introduction. In Halliday and Martin (1993c). pp. 2-21.

Halliday, M.A.K., and Martin, J.R. (1993c). *Writing science: Literacy and discursive power.* London: The Falmer Press.

Halliday M.A.K., McIntosh, A., and Strevens, P. (1964). *The linguistic sciences and language teaching.* London: Longman.

Halloran, M. (1978). Doing public business in public. In Campbell and Jamieson (eds.), 118-38.

Hanson, K. (1987). On subjectivity and the history of epistemic expressions in English. *Papers from the 23rd Regional Meeting,* Chicago Linguistic Society, Chicago (pp. 133-47).

Harder, B. H. (1984). Cultural attitudes in discourse analysis. *Canadian journal of Linguistics.* 29:115-130.

Harris, Sandra (1988). Court discourse as genre: some problems and issues. In Fawcett and Young (eds.), 94-115.

Hart, R. P. (1971). The rhetoric of the true believer. *Speech Monographs,* 38. As cited in Miller (1984).

Hasan, R. (1978). Text in the systemic functional model. In Dressler, W. U. (ed.). *Current trends in text linguistics.* Berlin and New York: W. de Gruyter.

Hasan, R. (1979). On the notion of text. In Petöfi, J.S. (ed), *Text vs. sentence: Basic questions of text linguistics*. Hamburg: Helmut Buske.

Hasan, R. (1989). Part B. In Halliday and Hasan, 52-118.

Henderson, W. and Hewings, A. (1990). A language of model building? In Dudley-Evans, T. and Henderson, W. (eds.). *The language of economics: the analysis of economics discourse*. ELT Documents 134. MEP and the British Council.

Hernadi, P. (1972). *Beyond genre: new directions in literary classification.*. Ithaca and London.

Herzberg, B. (1986). The politics of discourse communities. Paper presented at the CCC Convention, New Orleans, La., March, 1986. As quoted by Swales (1990).

Heslot, J. (1982). Tense and other indexical markers in the typology of scientific texts in English. In Hoedt *et al.* (eds.), (pp. 83-103).

Hewings, A. and Henderson, W. (1987). A link between genre and schemata: a case study of economics text. *ELR Journal*, 156-75.

Hill, S. S., Soppelsa, B. F., and West, G. K. (1982). Teaching ESL students to read and write experimental research papers. *TESOL Quarterly*, 16(3):333-47.

Hinds, J. (1983). Contrastive rhetoric: Japanese and English. *Text*, 3:183-96.

Hoedt, J., Lundquist, L., Pitch, H., and Quistgaard, J. (eds.). (1982). *Pragmatics and LSP: Proceedings of the 3rd European Symposium on LSP*. Copenhagen, August 1981. Copenhagen: School of Economics.

Hopkins, A. and Dudley-Evans, T. (1988). A genre-based investigation of the discussion sections in articles and dissertations. *English for Specific Purposes*, 7:113-22.

Huddleston, R.D. (1970). *The sentence in written English: A syntactic study based on an analysis of scientific texts*. Cambridge: Cambridge University Press.

Huddleston, R.D. (1988). Review Article. *Journal of Linguistics*, 24:137-74.

Huddleston, R.D., Hudson, R.A., Winter, E.O., and Henrici, A. (1968). *Sentence and clause in scientific English*. London: Office of Science and Technical information Report No. 5030.

Hudson, R. A. (1980). *Sociolinguistics*. Cambridge: CUP.

Hughes, Geraldine (1989). Article introductions in computer journals. Unpublished M.A. dissertation, University of Birmingham, U.K.

Hunt, K. (1965). *Grammatical structures written at three grade levels*. (Research Report No. 3). Urbana, IL: National Council of Teachers of English.

Hyland, K. (1990). A genre description of the argumentative essay. *RELC Journal*, 21(10):66-78.

Ingberg, M. (1987).Argumentative style in Finland-Swedish student compositions. Paper given at the Tenth Scandinavian Conference of Linguistics, Bergen, 11-13 June, 1987. (As reported by Maurannen, 1993.)

Jacoby, Sally (1986). The inevitable forked tongue: an analysis of references to other researchers in literary research articles. Unpublished M.A. Dissertation, University of Birmingham, U.K.

James, C. (1990). Learner language. *Language Teaching*, 23(4):205-13.

Jingfu, Peng (1987). Organisational features in chemical engineering research articles. *ELR Journal*, 1:79-116.

Johnson, D.M. and Roen, D.H. (eds) (1989). *Richness in writing*. White Plains, NY.: Longman.

Jones, L.B., and Jones, L.K. (1985). Discourse function of five English sentence types. *Word*, 36(1):1-21.

Jordan, M.P. (1984). *Rhetoric of everyday prose*. London: George Allen Unwin.

Kachru, Y. (1984). English and Hindi. *Annual Review of Applied Linguistics*, 3:50-77.

Kaplan, R.B. (1966). Cultural thought patterns in intercultural education. *Language Learning*, 16:1-20.

Kaplan, R.B. (1972). *The anatomy of rhetoric: Prolegomena to a functional theory of rhetoric*. Philadelphia: Center for Curriculum Development.

Kaplan, R.B. (1987). Cultural thought patterns revisited. In Connor and Kaplan (eds.), (pp. 9-20).

Kaplan, R.B. (1988). Contrastive rhetoric and second language learning: Notes towards a theory of contrastive rhetoric. In Purves, A.C. (ed), pp. 275-304.

Kibui, A. (1988). Aspects of hedging in the discourse of medical research discourse. MSc dissertation, Aston University, Birmingham, U.K.

Kies, D. (1988). Marked themes with and without pronominal reinforcement: Their meaning and distribution in discourse. In Steiner, E. and Veltman, R. (eds), *Pragmatics, discourse and text: Some systemically-inspired approaches*. London: Francis Pinter.

Knorr-Certina, K. D. (1981). *The manufacture of knowledge*. Oxford: Pergamon.

Kress, G.S. (ed) (1976). *Halliday: System and function in language*. London: Oxford University Press.

Kress, G.S. (1985). Ideological structures in discourse. In van Dijk, T.A. (ed.). *Handbook of discourse analysis: discourse analysis in society*, 27-42. London: Academic Press.

Kress, G. S. (1993). Genre as social process. In Cope and Kalantzis (eds). pp. 22-37.

Kurzon, D. (1988). The theme in text cohesion. In Tobin, Y. (ed). *The Prague School and its legacy*. Amsterdam: John Benjamins.

Lackstrom, J.E. (1978). The comprehension of EST: Arguments and definitions. *Studies in language learning*. Special issue on LSP, Vol. 2.

Lackstrom, J.E, Selinker, L., and Trimble, L.P. (1972). Grammar and technical English. *English Teaching Forum*, X(5):3-14.

Lakoff, G. (1972). Hedges: A study in meaning criteria and the logic of fuzzy concepts. *Papers from the 8th Regional Meeting*, Chicago Linguistic Society, April 14-16 (pp. 183-228). Also in *Journal of Philosophical Logic*, (1973), 1:458-508.

Latour, B. and Woolger, S. (1979). *Laboratory life: The social construction of scientific facts*. Beverly Hills, Cal.: Sage Publications.

Leech, G.N. (1983). *Principles of pragmatics*. London: Longman.

Leki, I. (1991). Twenty-five years of contrastive rhetoric: Text analysis and writing pedagogies. *TESOL Quarterly*, Vol. 25.

Lemke, J.L. (1985). Ideology, intertextuality, and the notion of register. In Benson and Greaves (eds.) (1985a), 275-94.

Lemke, J.L. (1988). Text structure and text semantics. In Steiner, E.H. and Veltman, R. (eds), pp. 158-170.

Lopez, G. S. (1982). Article introductions in Spanish: a study in comparative rhetoric. Unpublished M.Sc. Dissertation, University of Aston, U.K.

Lowe, I. (1987). Sentence initial elements in English and their discourse function. *Occasional Papers in Systemic Linguistics*, vol. 2. Nottingham: University of Nottingham.

Mackay, R., and Mountford, A. (eds) (1978).*English for Specific Purposes*. London: Longman.

Makaya, P. and Bloor, T. (1987). Playing safe with predictions: Hedging, attribution and conditions in economic forecasting. In Bloor, T. and Norrish, J. (eds). *Written language*. British Studies in Applied Linguistics 2. CILT.

Malcolm, L. (1987). What rules govern tense usage in scientific articles? *English for Specific Purposes*, 6(1):31-44.

Mann, W.C., and Thompson, S.A. (1987). Rhetorical structure theory: A theory of text organization. In Polanyi, L. (ed). *The structure of discourse*. Norwood, NJ: Ablex.

Mann, W.C., and Thompson, S.A. (eds) (1992). *Discourse dscriptions: Diverse analysis of a fund-raising text*. Amsterdam: Benjamins.

Martin, J.R. (1983). Conjunction: The logic of English text. In Petöfi, J.S. and Sözer, E. (eds).

Martin, J.R. (1984). Lexical cohesion, field and genre: Parcelling experience and discourse goals. *Proceedings of the Second Rice Symposium in Linguistics and Semiotics: Text Semantics and Discourse Semantics*, Feb., 1984.

Martin, J.R. (1985). Process and Text: two aspects of human semiotics. In Benson and Greaves (eds.) (1985a), 248-274.

Martin, J.R. and Rothery, J. (1981). *Working papers in linguistics*, Writing Project Report No. 2. Department of Linguistics, University of Sidney, Australia.

Mason, J. (1989). *Philosophical rhetoric: The function of indirection in philosophical writing*. London: Routledge.

Mathesius, V. (1939). On the so-called Functional Sentence Perspective. *Slovo a slovensnort*. Vol. 7, 177-84.

Maurannen, A. (1993). Contrastive ESP rhetoric: Metatext in Finnish-English economic texts. *English for Specific Purposes*, 12.

Maynard, S.K. (1986). Interactional aspects of thematic progression in English casual conversation. *Text*, 6(1):73-105.

McClosky, D. (1986). *The rhetoric of economics*. Madison, WI:University of Wisconsin Press.

McIntosh, A., and Halliday, M.A.K. (1964). *Patterns of language: Papers in general, descriptive and applied linguistics*. London: Longman.

McKay, S. and Rosenthal, L. (1980). *Writing for a specific purpose*. New Jersey: Prentice Hall.

McKinley, E. (1983). An analysis of discussion sections in medical journal articles. Unpublished M.A. Dissertation, University of Birmingham.

Miller, Carolyn R. (1984). Genre as social action. Quarterly Journal of Speech, 70:151-67.

Mohan, B. and Lo, A-Y. (1985). Academic writing and Chinese students: transfer and developmental factors. *TESOL Quarterly*, 19:515-34.

Mohramann, G.P., and Leff, M.C. (1974). Lincoln at Cooper Union: a rationale for neo-classical criticism. *Quarterly Journal of Speech*, 60:459-67.

Morris, J. E. (1966). *Principles of Scientific and Technical Writing*.New York: McGraw-Hill.

Myers, G. (1986). Reality, consensus, and reform in the rhetoric of composition. *College English*, 48(2):154-174.

Myers, G. (1988). The social construction of science and the teaching of English: An example of research. *ELT Documents*, 129:143-150.

Myers, G. (1989). The pragmatics of politeness in scientific articles. *Applied Linguistics*, 10(1):1-35.

Nash, W. (1990). Introduction: The stuff these people write. In Nash, W. (ed), pp. 8-30.

Nash, W. (ed) (1990). *The writing scholar: studies in academic discourse*. Newbury Park, Cal.: Sage Publications.

Nesbitt, C., and Plum, G. (1988). Probabilities in a systemic-functional grammar: the clause complex in English. In Fawcett and Young (eds.), 6-38.

Nwogu, K. N. (1990). *Discourse variation in medical texts: Schema, theme and cohesion in professional and journalistic accounts*. Monographs in Systemic Linguistics, Vol. 2. Nottingham: Department of English Studies, University of Nottingham.

Oster, Sandra (1981). The use of tense in reporting past literature. In Selinker, L., Tarone, E., and Hanzeli, V. (eds.). *English for academic and technical purposes: studies in honor of Louis Trimble*, (76-90). Rowley, Mass.: Newbury House.

Ostler, M. (1987). English in parallells: English and Arabic. In Connor and Kaplan (eds.).

Ostler, S.E. (1988). A study of the contrastive rhetoric of Arabic, English, Japanese and Spanish. *Dissertation Abstracts International*, 49(2):245A-246A.

Palmer, F.R. (1979). *Modality and the English modals*. London: Longman

Palmer, F.R. (1986). *Mood and modality*. Cambridge: CUP

Park, Y. M. (1988). Academic and ethnic background as factors affecting writing performance. In Purves (ed.).

Paterson, M. S. (1961). *Scientific Thinking and Scientific Writing*. New York: Rinehold.

Perelman, C., and Olbrechts-Tyteca, L. (1969). *The new rhetoric: A treatise on argumentation*. Notre Dame: University of Notre Dame Press.

Pèry-Woodley, M-P. (1990). Contrasting discourses: contrastive analysis and a discourse approach to writing. *Language Teaching*, 23(3):143-52.

Petöfi, J.S. and Sözer, E. (eds) (1983). *Papers in Text Linguistics.* Hamburg: Buske.

Purves, A. (ed.) (1988). *Writing across languages and cultures*. Newbury Park, CA: Sage Publications.

Quirk, R., and Greenbaum, S. (1973). *A unviersity grammar of English*. London: Longman.

Quirk, R., Greenbaum, S., Leech, G., and Svartvik, J. (1985). *A Comprehensive Grammar of the English Language*. London: Longman.

Rahman, Mujib (1991). Towards an evaluation of the CARS model: Article introductions in structural geology research papers. Unpublished M.Sc. Dissertation, University of Edinburgh.

Raskin, V. and Weiser, I. (1987). *Language and writing: Applications of linguistics to rhetoric and composition*. Norwood, NJ: Ablex.

Raum, R.D., and Measell, J.S. (1974). Wallace and his ways: a study of the rhetorical genre of polarization. *Central State Speech Journal*, 25:28-35. As cited in Miller (1984).

Ravelli, L.J. (1988). Grammatical metaphor: an initial analysis. In Steiner, and Veltman, (eds), pp. 133-147.

Redeker, G. (1990). Ideational and pragmatic markers of discourse structure. *Journal of Pragmatics*, 14:367-81.

Règent, O. (1985). A comparative approach to the learning of specialised written discourse. In Riley, P. (ed.). *Discourse and learning*. London & New York: Longman.

Reid, T.B.W. (1956). Linguistic, structuralism, and philology. *Archivium Linguisticum*, 8(2), No. 28.

Ringbom, H. (1987). *The role of the first language in second language learning*. Clarendon, Avon: Multilingual Matters.

Robinson, P. (1980). *ESP: English for specific purposes*. London: Pergamon.

Rogers, R.S. (1982). Generic tendencies in majority and non-majority supreme court opinions: the case of Justice Douglas. *Communication Quarterly*, 30:232-36.

Rounds, P.L. (1982). *Hedging in written academic discourse: Precision and flexibility*. Unp. Manuscript, Department of Linguistics, University of Michigan.

Salager-Meyer, F. (1992). A text-type and move analysis study of verb, tense and modality distribution in medical English abstracts. *English for Specific Purposes*, 11:93-113.

Salager-Meyer, F. (1994). Hedges and textual communicative function in medical English written discourse. *English for Specific Purposes*, 13(2):149-70.

Scarcella, Rubin (1984). How writers orient their readers in expository essays: a comparative study of native and non-native English writers. *TESOL Quarterly*, 18:671-88.

Schegloff, E.A., and Sacks, H. (1973). Opening up clisongs. *Semiotica*, 8(4):289-327.

Selinker, L., Trimble, L., and Vroman, R. (1974). *Working papers in English for science and technology*. College of Engineering, Seattle, University of Washington.

Selinker, L., Trimble, L., and Trimble, M.T. (1978). Rhetorical function-shifts in EST discourse. *TESOL Quarterly*, 12(3):311-20.

Shaw, P. (1992). Reasons for the correlation of voice, tense, and sentence function in reporting verbs. *Applied Linguistics*, 13(3):302-319.

Simons, H.W. (ed) (1989). *Rhetoric in the human sciences*. London: Sage.

Simpson, P. (1990). Modality in literary-critical discourse. In Nash, Walter (ed.), (63-94).

Sinclair, J.M. (1983). Planes of discourse. In Rizvil, S.N.A. (ed). *The two-fold voice: Essays in honour of Ramesh Mohan*. Hyderabad: Central Institute of English and Foreign Languages. (pp. 70-91).

Smith, Jr., E.L. (1985). Functional types of scientific prose. In Benson and Greaves (eds.) (1985b), 241-57.

Smith, Jr., E.L. (1986). Achieving impact through the interpersonal component. In Couture, B. (ed), pp. 108-119.

St. John, M. J. (1987). Writing processes of Spanish scientists publishing in English. *English for Specific Purposes*, 6(2):113-20.

Stalker, J. W. and Stalker, J. C. (1988). A comparison of pragmatic accommodation of nonnative and native speakers in written English. *World Englishes*, 7(2):119-128.

Steiner, E.H., and Veltman, R. (eds) (1988). *Pragmatics, discourse and text: some systemically inspired approaches*. London: Pinter.

Stenström, Anna-Brita (1994). *An introduction to spoken interaction*. London: Longman.

Strevens, P. (1977). Special purpose language learning: a perspective. *Language Teaching and Linguistics Abstracts*, 3(10):145-163.

Swales, J.M. (1981). *Aspects of article introductions*. Birmingham: University of Aston, Language Studies Unit.

Swales, J.M. (1983). Developing materials for writing scholarly introductions. In Jordan, R.R. (ed). *Case studies in ELT*, London: Collins (pp. 188-200).

Swales, J.M. (1984). Research into the structure of article introductions to journal articles and its application to the teaching of academic writing. *ELT Documents*, 117:7-86.

Swales, J.M. (1985). English language papers and authors' first language: Preliminary explorations. *Scientometrics*, 8(1-2):91-101.

Swales, J. M. (1987). Utilizing the literatures in teaching the research paper. *TESOL Quarterly*, 21:41-67.

Swales, J.M. (1988). Discourse communities, genres and English as an international language. *World Englishes*, 7, 211-220.

Swales, J. M. (1990). *Genre Analysis*. Cambridge: CUP.

Tadros, A. (1985). *Prediction in text.* ELR Monograph No. 10. Birmingham University.

Taglicht, J. (1984). *Message and emphasis: On focus and scope in English.* London: Longman.

Tarone, E. et al. (1981). On the use of the passive in two astrophysics journal papers. *The ESP Journal*, 1:123-40.

Taylor, G. (1986). Errors and explanation. *Applied Linguistics*, 7(2):144-66.

Taylor, G., and Tingguang, C. (1991). Linguistic, cultural, and subcultural issues in contrastive discourse analysis: Anglo-American and Chinese scientific texts. *Applied Linguistics*, 12(3):319-336.

Thibaudet, P. (1989). Genres, codes and pedagogy: Towards a critical social semiotic account. *Southern Review*, 21(3):243-64.

Tirkkonen-Condit, S. (1988). Explicitness vs. implicitness of argumentation: An intercultural comparison. Lecture at a colloquium `The Role of Argument in the Creationa and Maintenance of Community'. Venice, 7-11 August, 1988. (As cited by Maurannen, 1993.)

Tirkkonen-Condit, S. and Liefländer-Koistinen, L. (1989). Argumentation in Finnish versus English and German editorials. In Kusch, M. and Schröder, H. (eds), *Text, Interpretation, Argumentation*. pp. 173-81.

Thompson, G., and Yiyun, Ye (1991). Evaluation in reporting verbs used in academic papers. *Applied Linguistics*, 12(4):365-82.

Thompson, S., and Mann, W.C. (1987). Rhetorical structure theory: A framework for the analysis of texts. *Papers in Pragmatics*, 1(1):79-105.

Todorov, T. (1976). The origin of genres. *New Literary History*, 8:159-70.

Todorov, T. (1971). *La poetique de la prose*. Seuil: Paris. (Translated 1977: *The poetics of prose*. New York: Cornell University Press.)

Todorov, T. (1990). *Genres in discourse*. Cambridge: CUP. (Translated by Catherine Porter.)

Toulmin, S. (1958). *The uses of argument*. Cambridge: Cambridge University Press.

Travenicek, F. (1951). *Grammar of standard Czech*. Prague.

Trimble, L. (1985). *English for science and technology: A discourse approach.*. Cambridge: Cambridge University Press.

Trimble, M.T., and Trimble, L. (1982). Rhetorical-grammatical features of scientific and technical texts as a major factor in written ESP communication. In Hoedt, *et al.* (eds.), (119-216).

Vanda Kopple, W.J. (1983). Something old, something new. *Research in the Teaching of English*, 17:85-99.

Vande Kopple, W.J. (1985). Some exploratory discourse on metadiscourse. *College Composition and Communication*, 36:82-93.

Van Naerssen, M. M. (1980). How similar are Spanish as a first language and Spanish as a foreign language? In Scarcella, R. and Krashen, S. D. (eds.). *Issues in second language research*. Rowley, MA: Newbury House.

Ventola, E. (1984). The dynamic of genre. *Nottingham Linguistic Circular* (Special issue on Systemic Linguistics), 13:103-23.

Ventola, E. (1988). Text analysis in operation: a multilevel approach. In Fawcett and Young (eds.), 52-77.

Ware, B.L., and Linkugel, W.A. (1973). They spoke in defence of themselves: on the generic criticism of apologia. *Quarterly J. of Speech*, 59:273-83. As cited in Miller (1984).

Weber, Hartmut (1982). Language for specific purposes, text typology, and text analysis: aspects of a pragmatic-functional approach. In Hoedt *et al.* (eds.).

Weill, H. (1884). *The order of words in the ancient languages compared with that of modern languages*. Boston. (Re-edited, Amsterdam, 1978).

Weissberg, R.C. (1984). Given and new: Paragraph development models from scientific English. *TESOL Quarterly*, 18(3):485-500.

Weissberg, R. and Buker, S. (1990). *Writing up research*. Englewood Cliffs, NJ: Prentice Hall.

Wellek, R., Warren, A. (1963). *The theory of literature*. London: Peregrine (3rd edition).

West, G.K. (1980). That-nominal constructions in traditional rhetorical divisions of scientific research papers. *TESOL Quarterly*, 14(4):483-88.

White, R.V. (1974). The concept of register and TESOL. *TESOL Quarterly*, 8(4):401-16.

White, R.V. (1975). The langauge, the learner and the syllabus. *RELC Journal*, 6(1).

Widdowson, H.G. (1978). *Teaching language as communication.* Oxford: Oxford University Press.

Widdowson, H.G. (1979). *Explorations in Applied Linguistics*, Vol. 1. Oxford: Oxford University Press.

Widdowson, H.G. (1983). *Learning purpose and language use*. Oxford: OUP.

Widdowson, H.G. (1984). *Explorations in Applied Linguistics*, Vol. 2. Oxford: Oxford University Press.

Windt, Jr. T.O. (1972). The diatribe: last resort for protest. *Quarterly . of Speech*, 58:1-14.

Wingard, P. (1981). Some verb forms and functions in six medical texts. In Selinker, L. et al. (eds.). *English for academic and technical purposes*. Rowley, Mass: Newbury House.

Witte, S.P. (1983). Topical structure and revision. *College Composition and Communication*, 34(3):313-41.

Wong, S-L. C. (1988). What we do and don't know about Chinese learners of English: a critical review of selected research. *RELC Journal*, 19:1-20.

Wood, A.S. (1982). An examination of the structure of authentic chemistry texts. *Applied Linguistics*, 3(2):121-43.

Young, D.J. (1980). *The structure of English clauses*. London: Hutchinson.

Zappen, J. P. (1983). A rhetoric for research in sciences and technologies. In Anderson, P. V., Brockman, R. J., and Miller, C. R. (eds.). *New essays in technical and scientific communication*, (123-38). Farmingdale, NY.:Baywood.

APPENDIX A-1

List of Native Research Articles

NS-01 Tolbachite, CuCl2, the first example of Cu2+ octahedrally coordinated by Cl-. *American Mineralogist*, Vol. 78, pp. 187-189.

NS-02 Kinetics of the marcasite-pyrite transformation: An infrared spectroscopic study. *American Mineralogist*, Vol. 77, pp. 1166-1171.

NS-03 Sieve-textured plagioclase in volcanic rocks produced by rapid decompression. *American Mineralogist*, Vol. 77, pp. 1242-1249.

NS-04 The applicability of least squares in the extraction of thermodynamic data from experimentally bracketed mineral equilibria. *American Mineralogist*, Vol. 78, pp. 107-112.

NS-05 Dielectric constants of diaspore and B-Be-, and P-containing minerals, the polarizability of B2O3 and P2O5, and the oxide additivity rule. *American Mineralogist*, Vol. 77, pp. 101-106.

NS-06 Formation of fluid inclusions and etch tunnels in olivine at high pressure. *American Mineralogist*, Vol. 77, pp. 296-203.

NS-07 Theoretical studies of the speciation of Al in F-bearing aluminosillicate glasses. *American Mineralogist*, Vol 78, pp. 16-22.

NS-08 Calculated frequencies of O-H stretching from different local orderings of Fe and Mg in simple clinoamphiboles. *Canadian Mineralogist*, Vol 30, pp. 335-342.

NS-09 Topaz: energy calculations bearing on the location of hydrogen. *Canadian Mineralogist*, Vol. 28, pp. 827-833.

NS-10 Gladstone-Dale constants fro the major elements in silicates: coordination number, polarizability, and the Lorentz-Lorentz relation. *Canadian Mineralogist*, Vol. 29, pp. 525-532.

NS-11 Ammonium in zeolitized of the Karlovassi Basin, Samos, Greece. *Canadian Mineralogist*, Vol 30, pp. 423-430.

NS-12 The timing of alkali metasomatism in paleosols. *Canadian Mineralogist*, Vol. 29, pp. 1043-1050.

NS-13 Mineralogy of rare-earth-bearing "thucholite", Parry Sound, Ontario. *Canadian Mineralogist*, Vol. 28, pp. 357-362.

NS-14 A gahnite-garnet retrograde reaction from the Pinnacles Deposit, Broken Hill, New South Wales, Australia. *Canadian Mineralogist*, 30:145-152.

NS-15 Structural state of the K-feldspar in the Butler Hill - Breadtray Granite, St. Francois Mountains, SE Missouri. *Canadian Mineralogist*, Vol. 30, pp. 367-376.

NS-16 Routine trace-element capabilities of electron-microprobe analysis in mineralogical investigations: an empirical evaluation of performance using spectrochemical standard glasses. *Canadian Mineralogist*, Vol. 28, pp. 171-180.

NS-17 Massive sulfides with fluid-inclusion-bearing quartz from a young seamount on the East Pacific Rise. *Canadian Mineralogist*, Vol. 29, pp. 453-460.

NS-18 Thermoluminescence spectra of mineral. *Min. Magazine*, Vol. 57, pp. 217-222.

NS-19 Composition of fluids in quartz: discrimination of magma pulses in a Caledonian granitoid. *Min. Magazine*, Vol. 56, pp. 335-342.

NS-20 Deformation textures in Pyrite from the Vangorda Pb-Zn-Ag deposit, Yukon, Canada. *Min. Magazine*, Vol. 57, pp. 55-66.

NS-21 A supposed sovite from Oldoinyo Lengai, Tanzania: result of extreme alteration of alkali carbonatite lava. *Min. Magazine*, Vol. 57, pp. 93-101.

NS-22 The stabilities of secondary tin minerals: abhurite and its relationships to Sn(II) and Sn(IV) oxides and oxyhydroxides. *Min. Magazine*, Vol 56, pp. 221-226.

NS-23 Sulphide mylonites from the Renstron VMS deposit, Northern Sweden. *Min. Magazine*, Vol. 57, pp. 83-91.

NS-24 Low-pressure corona textures between olivine and plagioclase in unmetamorphosed gabbros from Black Hill, South Australia. *Min. Magazine*, Vol. 56, pp. 503-509.

NS-25 Petrogenetic implications of garnet associated with lithium pegmatites from SE Ireland. *Min. Magazine*, Vol. 56.

NS-26 The rheology of faults triggered by the olivine-spinel transformation in Mg2GeO4 and its implications for the mechanism of deep-focus earthquakes. *J. of Structural Geology*, Vol. 15/9-10, pp. 1249-1256.

NS-27 A footwall system of faults associated with a foreland thrust in Montana. *J. of Structural Geology*, Vol. 15/3-5, pp. 335-342.

NS-28 The interplay between fluids, folds and thrusts during the deformation of a sedimentary succession. *J. of Structural Geology*, Vol 15/3-5, pp. 491-500.

NS-29 Constant bed-length folding: three-dimensional geometrical implications. *J. of Structural Geology*, Vol. 14/2, pp. 245-252.

NS-30 Three-dimensional finite strain from crinoid ossicles. *J. of Structural Geology*, Vol. 13/9, pp. 1049-1059.

APPENDIX A-2

List of Pakistani Research Articles[1]

PAK-01 A-Type granites of Warsak, Khyber Agency, N. Pakistan: Rift-related acid magmatism in the Indian plate.

PAK-02 Heavy mineral analysis of the molasse sediments, trans-Indus Ranges, Kohat, Pakistan.

PAK-03 Shallow marine sediments of the Patala Formation of Paleocene age, Kohat area, Pakistan.

PAK-04 Structures in the hangingwall of the main boundary thrust: Post-folding thrust and normal faults from the Kotal-Pass area, Kohat Range, N. Pakistan.

PAK-05 The Tora Tigga complex, Southern Dir, NW Pakistan: An example of mafic-ultramafic rocks in The bottom of an island arc.

PAK-06 Petrology of the Shewa-Shabazgarhi complex, Mardan, North Pakistan.

PAK-07 Sodic pyroxenes and amphiboles from Koga syenites of Ambela Granitic complex, N.W.F.P., Pakistan..

PAK-08 Large scale vertical aggradation of sandstones in the Kamlial Formation of the Kohat Basin, Pakistan.

PAK-09 Structure and stratigraphy of the Northern Gandghar Range, Hazara, Pakistan.

PAK-10 Petrology and the grain size characters of the Pab sandstone of parts of the Loralai and Khuzdar districts of Baluchistan.

PAK-11 Lithofacies associations and paleocurrent patterns in the Nagri Formation of the Siwalik group in Kach-Zarghun area of Northeast Baluchistan.

PAK-12 Stratigraphic control for the age of Peshawar-plain magmatism, Northern Pakistan.

PAK-13 Myrmekite in the Ambela Granitic Complex, N. Pakistan: A product of deformation and replacement in the feldspar.

PAK-14 Petrography and geochemistry of the inclusions from the Ambela Granitic Complex, N. Pakistan.

PAK-15 Stratigraphy of the Dungan group in Kach-Ziarat area, NE Balochistan.

PAK-16 Clay mineralogy of the quaternary lake deposits of Peshawar Basin, at Jehangira, district Mardan, N.W.F.P., Pakistan.

PAK-17 Island arc signatures from the Waziristan igneous complex, N.W.F.P., Pakistan.

---

[1] As already mentioned in Chapter 3, the source of all these RAs is the same: *Geological Bulletin*, University of Peshawar.

PAK-18 Petrology of Kakul phosphorites, District Abbottabad, N.W.F.P., Pakistan.

PAK-19 Sedimentology of the Ghazij Formation, Kach area, Baluchistan.

PAK-20 Preliminary petrochemical study of the Chilas complex, Kohistan island arc, Northern Pakistan.

PAK-21 Petrology of the Swat amphibolites and the development of a "Lesser Himalayan" Basin.

PAK-22 Geology and petrology of the Malakand granite, gneiss and metasedimentary complex.

PAK-23 Petrology of the Bibai volcanics, NE Baluchistan.

PAK-24 Ultramafic and mafic rocks of Thurly Gah and their relationship to the Chilas complex, N. Pakistan.

PAK-25 Mineralogy of the blueschist facies metagraywacke from the Shergarh Sar area, Allai Kohistan, N. Pakistan.

PAK-26 Shear waves provide an extra control on seismic interpretations.

PAK-27 Tectonic significance of mylonites from Mingora, Swat.

PAK-28 Major and trace element variations in the lavas of Shergarh Sar area and their significance with respect to the Kohistan Tectonic anomaly.

PAK-29 Coronites from the Chilas and Jijal-Patan complexes of Kohistan.

PAK-30 Petrochemistry of the rocks from Babaji area, a part of the Ambela Granitic complex, Buner, Northern Pakistan.

APPENDIX A-3

Sectional divisions of the RAs in the NATIVE dataset

RA NO.	INTRODUCTION	METHOD	RESULTS	DISCUSSION	CONCLUSION(S)	JOURNAL
NS-01	Y	Y	N	Y	N	AM
NS-02	Y	Y	Y	Y	N	AM
NS-03	Y	Y	Y	Y	N	AM
NS-04	Y	N	N	Y	Y	AM
NS-05	Y	Y	Y	Y	N	AM
NS-06	Y	Y	Y	Y	N	AM
NS-07	Y	Y	Y	Y	Y	AM
NS-08	Y	Y	Y	Y	Y	CM
NS-09	Y	Y	Y	Y	Y	CM
NS-10	Y	Y	Y	Y	Y	CM
NS-11	Y	Y	(Y)	Y	N	CM
NS-12	Y	Y	Y	Y	Y	CM
NS-13	Y	N	N	Y	N	CM
NS-14	Y	Y	(Y)	Y	N	CM
NS-15	Y	Y	Y	Y	N	CM
NS-16	Y	Y	Y	Y	Y	CM
NS-17	Y	Y	N	Y	N	CM
NS-18	Y	Y	Y	Y	Y	MM
NS-19	Y	(Y)	Y	Y	N	MM
NS-20	Y	N	N	Y	N	MM
NS-21	Y	N	N	Y	(Y)	MM
NS-22	Y	Y	Y	Y	N	MM
NS-23	Y	N	N	Y	Y	MM
NS-24	Y	N	N	Y	N	MM
NS-25	Y	N	N	Y	Y	MM
NS-26	Y	Y	Y	Y	Y	JSG
NS-27	Y	N	N	Y	Y	JSG
NS-28	Y	N	N	Y	Y	JSG
NS-29	Y	N	N	Y	Y	JSG
NS-30	Y	N	N	Y	N	JSG

Y Section present as such. (Y) Identifiable or different Heading. N Section absent.

[.....] Sections subsumed into one section: such as Discussion and Conclusion; Results and Discussion, etc.

AM American Mineralogist; CM Canadian Mineralogist; MM Mineralogical Magazine; JSG J.of Structural Geology

APPENDIXA-4

Sectional divisions of the RAs in the PAKISTANI dataset

RA NO.	INTRODUCTION	METHOD	RESULTS	DISCUSSION	CONCLUSION(S)	JOURNAL
PAK-01	Y	N	N	Y	N	GB
PAK-02	Y	(Y)	N	Y	N	GB
PAK-03	Y	N	N	Y	N	GB
PAK-04	Y	N	N	Y	Y	GB
PAK-05	Y	Y	Y	Y	N	GB
PAK-06	Y	N	N	Y	Y	GB
PAK-07	Y	Y	Y	Y	Y	GB
PAK-08	Y	N	N	Y	N	GB
PAK-09	Y	N	N	Y	N	GB
PAK-10	Y	N	Y	Y	Y	GB
PAK-11	Y	N	N	Y	Y	GB
PAK-12	Y	N	N	(Y)	N	GB
PAK-13	Y	N	N	Y	Y	GB
PAK-14	Y	N	N	Y	Y	GB
PAK-15	Y	N	N	Y	N	GB
PAK-16	Y	Y	N	Y	Y	GB
PAK-17	Y	N	N	Y	Y	GB
PAK-18	Y	N	N	Y	N	GB
PAK-19	Y	N	N	Y	Y	GB
PAK-20	Y	N	N	Y	Y	GB
PAK-21	Y	N	N	Y	Y	GB
PAK-22	Y	N	N	Y	Y	GB
PAK-23	Y	N	N	Y	N	GB
PAK-24	Y	N	N	Y	Y	GB
PAK-25	Y	N	N	Y	N	GB
PAK-26	Y	N	N	(Y)	Y	GB
PAK-27	Y	N	N	Y	Y	GB
PAK-28	Y	N	N	Y	N	GB
PAK-29	Y	N	N	Y	N	GB
PAK-30	Y	N	N	Y	N	GB

Y Section present as such. (Y) Identifiable or different Heading. N Section absent.
[.....] Sections subsumed into one section: such as Discussion and Conclusion; Results and Discussion, etc.
GB Geological Bulletin, University of Peshawar, Pakistan.

APPENDIXA-5

Length in words of each RA Section (Native Dataset)

	ABSTRACT (A)	INTRODUCTION (B)	DEVELOPMENT (C)	DISCUSSION (D)	CONCLUSION	TOTAL (B+C+B)
	WORDS	WORDS	WORDS	WORDS	WORDS	WORDS
NS-01	100	382	350	354	1086	
NS-02	96	792	1217	720		2729
NS-03	147	522	1722	1500		3744
NS-04	265	837	1559	360		2756
NS-05	173	193	1088	548		1829
NS-06	225	124	1816	894		2834
NS-07	263	520	2290	726	120	3656
NS-08	252	616	1401	812	192	3021
NS-09	246	574	1425	863	351	3213
NS-10	121	648	700	1712	147	3207
NS-11	110	483	1586	706		2775
NS-12	174	375	962	853	216	2406
NS-13	84	509	660	962		2131
NS-14	129	312	1135	963		2410
NS-15	148	578	1222	768		2568
NS-16	172	346	1951	1714	124	4135
NS-17	184	285	1274	690		2249
NS-18	129	189	538	1322	72	2121
NS-19	91	134	1266	589		1989
NS-20	179	270	2263	790		3323
NS-21	77	264	1344	840		2448
NS-22	66	755	981	789		2525
NS-23	209	302	1079	378	185	1944
NS-24	236	187	1024	1322		2533
NS-25	125	391	1516	1320	289	3516
NS-26	152	462	1072	741	311	2586
NS-27	180	173	1646	694	214	2727
NS-28	76	362	2447	622	160	3591
NS-29	267	233	2149	241		2623
NS-30	164	554	2606	485		3645
TOTAL:	4840	12372	42289	25287	2381	82329
MEAN:	161.33	412.40	1409.63	842.90		2744.30
S:	62.07	198.46	564.24	378.70		670.29

APPENDIXA-6

Length in words of each RA Section (Pakistani Dataset)

	ABSTRACT (A)	INTRODUCTION (B)	DEVELOPMENT (C)	DISCUSSION (D)	CONCLUSION	TOTAL (B+C+D)
	WORDS	WORDS	WORDS	WORDS	WORDS	WORDS
PAK-01	128	172	2857	478		3507
PAK-02	241	284	1795	630		2709
PAK-03	93	205	1824	635		2664
PAK-04	187	310	1115	310	96	1831
PAK-05	146	354	3200	752		4306
PAK-06	229	357	3326	1689		5372
PAK-07	107	183	1943	537	114	2777
PAK-08	138	379	882	430		1691
PAK-09	135	265	2240	585		3090
PAK-10	89	236	927	2109	66	3338
PAK-11	224	263	891	382	112	1648
PAK-12	119	329	781	1066		2176
PAK-13	116	222	844	645	170	1881
PAK-14	90	158	595	378		1131
PAK-15	252	394	2686	406		3486
PAK-16	88	268	903	539	162	1872
PAK-17	111	470	832	1135	158	2595
PAK-18	74	323	480	183		986
PAK-19	150	258	711	223	74	1266
PAK-20	155	559	1247	1543	294	3643
PAK-21	122	394	1962	369	230	2955
PAK-22	148	290	1518	1090	159	3057
PAK-23	97	323	1474	433		2230
PAK-24	151	403	3184	669		4256
PAK-25	95	305	1025	232		1562
PAK-26	91	296	377	745	99	1517
PAK-27	71	406	1748	197	120	2471
PAK-28	179	207	1783	463		2453
PAK-29	168	251	1664	644		2559
PAK-30	72	251	692	262		1205
TOTAL:	4066	9115	45506	19759	1854	76234
MEAN:	135.53	303.83	1516.86	658.63		2541.13
SD:	51.08	90.62	856.68	460.36		1043.23

APPENDIX B-1

Outline Structure of NATIVE RA introductions

RA NO.	MOVES	Ss	SIGNALS (my emphases)
NS-01	1.1	(1-2)	Tolbachite, CuCl2, occurs in encrustations on basaltic magma .... It is hygroscopic and hydrates to ....
	2.1b	(3-4)	This feature, ... presents special problems for structure characterisation. The crystal structure of synthetic CuCl2 was determined by Wells (), but because of the ... problems was not refined.
	1.3	(5)	...
	3.1b	(6-14)	We are currently interested in bond-distance variations in CuCl2 ....
		(15-16)	We have refined the crystal structure ....
NS-02	1.1	(1)	Pyrite and marcasite are naturally occurring phases in the Fe-S system ....
	B	(2-8)	The pyrite crystal structure is cubic .... [...].
	1.2	(9)	Marcasite readily inverts to pyrite when heated under vacuum ....
	1.3	(10-15)	Murowchick and Barnes () ... [...].
	2.1a	(16)	The formation and persistence of marcasite is thus due not to its thermodynamic stability but to kinetic factors.
	1.3	(17-31)	Whereas pyrite ... (). Tossell et al., () ... [...].
	3.1a	(32)	The present study was undertaken to measure the activation energy ....
NS-03	1.1	(1)	Plagioclase commonly exhibits a variety of ....
	1.2	(2)	These textures often include ... in magmatic systems.
	2.1d	(3)	Thus the potential exists to learn much about magmatic processes .... [...].
	3.1b	(4-12)	This study deals with .... We interpret the texture of .... [...].
	1.3	(13-17)	......
	3.2	(18-20)	However, our results indicate that .... [...].
NS-04	1.1	(1)	With the ever increasing volume of experimental ... data on minerals a thermodynamic data set ... is becoming attainable.
	1.2	(2)	An important stage in this development was the recognition that ....
	1.3	(3-5)	So-called internally ... data sets involve .... Two methodologies ... proposed ... [...].
	2.1a	(6)	There have been some suggestions that various aspects of the LSQ approach make it inappropriate for data extraction: >
	3.1a	(6-9)	the aim of this paper is to show why the LSQ approach is not only sound, but also the most appropriate approach. [...].
	3.3	(10-28)	We will start by showing how .... [...].
	3.1a	(29-31)	Discussion of these and related points is the focus of this paper. It will be shown that .... [...].
NS-05	1.1	(1)	Dielectric polarizability, ÂD, is related to ....
	1.2	(2)	The Clausius-Mosotti equation is strictly valid only for .... >
	2.1b		but has been shown to be approximately valid for ....
	1.3	(3-4)	The concept of additivity .... Previous applications ... reviewed by ....
	3.1b	(5)	The purpose of this paper ....

1. ... indicates text omissions.
2. [...] indicates sentence omissions.
3. () indicates citation omissions.
4. > indicates next clause begins a new STEP.
5. B Background Information
6. M Method Step

RA NO.	MOVES	Ss	SIGNALS (my emphases)
NS-06	1.1	(1)	During the course of experiments to measure ... by 7-track autoradiography .... >
	1.2	(1)	it was noted that some specimens annealed ....
	2.1b	(2)	The tubes we have produced at high pressure are similar ....
	1.3	(2)	(6 citations in parenthesis.)
	3.1b	(3)	We have characterised these experimentally induced features ....
NS-07	1.1	(1)	Dissolved volatile components in magmas can strongly influence ....
	1.2	(2-3)	F is one of the most important volatile components .... [...].
	1.3	(4)	...
	2.1b	(5-8)	Although some features in the Al ... could be assigned fairly confidently ... certain weak features could not be so confidently assigned. [...].
	1.3	(9-14)	...
	3.1b	(15)	To assist in assigning the 27Al and 19F NMR spectra ... >
	M	(15-18)	we have calculated using quantum mechanics .... For each species, we calculate .... we then calculated .... we have also calculated ....
NS-08	1.1	(1)	Abbot developed and tested a method to determine the short-range potential ....
	1.2	(2-5)	The short-range potential was modeled as a simple .... The method involved .... [...].
	2.1b	(6-7)	Whereas ... seems to transfer well ... transferability to ... is less straightforward.
	1.3	(8-9)	It is quite well understood .... [...].
	2.1b	(10-12)	A further complication has to do with .... [...].
	1.3	(13-19)	Observation () suggests that ... [...].
	3.1b	(20)	In this paper, we use Distance-Least-Squares (DLS) analysis to create .... [...]
	M	(21-23)	Then, using the method of Abbott (), we .... [...].
NS-09	1.1	(1)	The major mechanism of solid solution in topaz involves ...
	1.2	(1)	but in natural samples of topaz the fraction ....
	1.3	(2-3)	...
	2.1b	(4)	However, the optical properties ... are not always consistent ....
	1.3	(5-18)	...
	3.1a	(19-20)	In the work presented in this paper .... The purpose is to test ....
NS-10	1.1	(1)	The concept of ... is firmly enshrined in the mineralogical literature .... [...].
	1.2	(2-3)	The Lorentz-Lorentz law has a theoretical basis .... [...].
	2.1b	(4)	In contrast ... the Gladstone-Dale ... does not appear to have any theoretical basis....
	1.3	(5-18)	...
	3.1b	(19-20)	The present study ....
NS-11	1.1	(1-4)	The ammonium ion is widely distributed ... in igneous rocks. [...].
	1.2	(5)	Any ammonium present in ... is therefore secondary in origin.
	2.1b	(6)	There have been many studies of ammonium ... but pyroclastic rocks have not been ....
	1.3	(7-8)	Zeolitic tuffs are potentially .... ().
	3.1a	(9-10)	This is essentially a reconnaisance study .... [...].
	1.3	(11-23)	During the late Miocene, the Aegean region .... [...]

1. ... indicates text omissions.
2. [...] indicates sentence omissions.
3. () indicates citation omissions.
4. > indicates next clause begins a new STEP.
5. B Background Information
6. M Method Step

RA NO.	MOVES	Ss	SIGNALS (my emphases)
NS-12	1.1	(1)	Paleosols are lithified weathering profiles ....
	1.2	(2-5)	The distribution of iron in paleosols and ... may be used as indicators .... [...].
	1.3	(6-11)	Several examples of such soils have been discovered .... [...].
	2.1a	(12-14)	Residual enrichment alone thus cannot explain the present alkali contents of the paleosols.
	3.1a	(15)	To test this hypothesis and to gain further insight ... >
	M	(15)	we performed Rb-Sr analyses on whole-rock samples ....
	?	(16)	Future papers will consider the mobilization ....
NS-13	B	(1-5)	Metal-rich solid pyrobitumens described as "thucholite" occur at numerous localities ....
	1.1	(6-7)	The occurrence of thucholite ... has suggested to some workers a ... (). [...].
	1.2	(8)	Given that ... it is very likely ...
	1.3	(9-15)	It is known that ... [...].
	2.1b	(16)	The distribution of heavy metals ... thucholite has not been previously described.
	3.1b	(17-18)	The present paper reports .... [...].
	3.2	(19-21)	The elements detected .... [...].
NS-14	1.1	(1-2)	The spinel gahnite represents .... [...].
	1.2	(3)	The high Zn content ... make it a potential indicator ...
	1.3	(4-8)	Several theories have been proposed .... [...].
	3.1b	(9)	This contribution documents one particularly unusual occurrence ....
	2.1b	(10)	The association of ... rocks has not been described previously ....
NS-15	B	(1-2)	The St. Francois Mountains ... represent the best exposure .... [...].
	1.1	(3)	The Butler Hill-Breadtray granite is the largest pluton exposed ....
	1.2	(4)	This pluton is interpreted to have formed .... ()
	1.3	(5-13)	...
	2.1b	(14)	The factors ... are numerous .... () and there does not yet seem to be a consensus ....
	1.3	(15-16)	...
	3.1a	(17)	The purpose of this study was ....
NS-16	1.1	(1)	Quantitative information ... is needed for a variety of applications ....
	1.2	(2)	Microbeam techniques ... are the only ones able to obtain such information in situ.
	2.1d	(3-4)	Each has its advantages and disadvantages. The superior spacial resolution of the electron microprobe, however, means that this instrument must be used where ....
	1.3	(5-8)	...
	3.1a	(9-10)	The aim of the present study .... [...].
NS-17	1.1	(1)	Seafloor sulfide deposits have been discovered at many sites ....
	1.2	(2)	Known sulfide deposits from seamounts are less abundant ....
	1.3	(3-6)	Those from young seamounts ... have been described and analyzed by () .... [...].
	2.1b	(7-8)	The relative importance ... is unknown. However, ... could play an important role ... ().
	3.1b	(9-11)	The present paper .... [...].

1. ... indicates text omissions.
2. [...] indicates sentence omissions.
3. () indicates citation omissions.
4. > indicates next clause begins a new STEP.
5. B Background Information
6. M Method Step

RA NO.	MOVES	Ss	SIGNALS (my emphases)
NS-18	1.1	(1-3)	Thermoluminescence (TL) is a sensitive technique for studying defects ....[...].
	1.2	(4)	TL spectra provide important information on ... defects, and ....
	1.3	(5)	A review of the potential information ... is given by ().
	2.1b	(6)	There is a variety of techniques .... not all methods reveal the same defects.
	3.1b	(7-8)	Luminescence methods ... are complementary ... By contrast, CL provides ....
NS-19	1.1	(1)	The important role of fluids in mineralisation ... has been recognised for a long time ....
	1.2	(2)	Chemical analysis of the fluids ... has been achieved both by ....
	2.1b	(3)	Most analytical studies on fluids [however] have concentrated on ....
	3.1b	(4)	This work describes the qualitative determination ... >
	3.2	(4)	which highlights a strong link between ....
NS-20	B	(1-8)	The Vangorda deposit is a 7.1 million tonne, ... massive sulphide orebody .... [...].
	1.1	(9)	Pyrite ... has been shown to deform by brittle mechanisms ... [...].
	1.2	(10)	It has further been demonstrated ...
	1.3	(11)	Cox () experimentally determined ...
	2.1b	(12)	Dynamic recrystallisation ... though not a widely reported feature ...
	3.1b	(13-14)	This paper examines .... [...].
NS-21	1.1	(1-3)	Oldoinyo Lengai ... is the world's only active carbonatite volcano. [...].
	1.2	(4)	During the 1960 survey of Oldoinyo Lengai, I collected an angular block ....
	1.3	(5)	It was identified as calcite carbonatite ... and I have reported it as sovite ... ().
	2.1d	(6)	A re-examination of this specimen has been prompted in view of its potential relevance ....
	1.3	(7)	Gitten () has argued that ...
	3.1b	(8-9)	Because ... the investigation was extended to a study of ... Also examined ...
NS-22	1.1	(1-4)	The corrosion of tin in saline environments usually results .... [...].
	1.2	(5)	More recent investigations have pointed ... only one basic tin (II) chlorite exists ...
	1.3	(6-9)	Randall and Murkami () ... Donaldson et al., () ... [...].
	2.1b	(10-11)	However, von Schnering et al., () have determined ... and showed that .... Nevertheless, this has been overlooked by recent investigators.
	1.3	(12-22)	...
	2.1c	(23-25)	It would be a difficult task to derive .... [...].
	2.1a	(26)	Comparison of the reported analytical data with that for ... indicates that ... is the correct formula, rather than ... as originally suggested.
	3.1a	(27-32)	For some time, we have been interested in describing .... [...].
		(33)	The results of the study are reported below.
NS-23	1.1	(1)	Mylonites are rocks found in shear zones ....
	1.2	(2-4)	There are various microscale processes that serve to accommodate ....
	2.1b	(4)	but despite this, many deformation textures in the sulphides are either not recognised or not reported, and may have been misinterpreted as primary textures.
	1.3	(5-9)	...
	3.3?	(10-11)	However, it is most commonly observed ... The weaker sulphides ... whilst ... may deform ... if efective confining pressures are low.

1. ... indicates text omissions.
2. [...] indicates sentence omissions.
3. () indicates citation omissions.
4. > indicates next clause begins a new STEP.
5. B Background Information
6. M Method Step

RA NO.	MOVES	Ss	SIGNALS (my emphases)
NS-24	1.1	(1)	Reaction coronas between ... are a common feature of many gabbroic rocks.
	1.2	(2)	In general, such coronas formed at high pressures ....
	1.3	(3)	Coronas are usually described ... ().
	2.1b	(4)	However, there has been some considerable debate ... ().
	3.1b	(5-6)	Here we report on new symplectite reaction coronas ....
	3.2	(7)	The physico-chemical conditions during corona formation are ... different ....
NS-25	B	(1-3)	Garnets are common in metamorphic rocks .... [...].
	1.1	(3)	The origin of garnets in granitic rocks has long been a subject of debate ...
	1.3	(4-5)	Essentially three modes of origin have been proposed ... [...].
	1.2	(6-7)	The presence and ... permit conclusions to be drawn ... [...].
	2.1d	(8)	This information ... and fluid inclusion data may give further insignts ...
	3.1b	(9)	Accordingly, this paper documents ....
	M	(10-13)	Fifty-five analyses of garnet were performed on a ... microprobe ... [...].
NS-26	1.1	(1)	Deep-focus earthquakes have been a paradox since their discovery ....
	1.2	(2)	Their seismic characteristics are virtually indistinguishable from ....
	1.3	(3-8)	Thus, it has been argued ... [...].
	2.1a	(9-14)	Despite its remarkable similarity to ... several aspects ... indicate that ....
	3.1a	(15)	The principal goal of this study ....
	3.2	(16-18)	The observed pressure ... indicate that sliding is not controlled by friction. [...].
NS-27	1.1	(1-2)	There are several aproaches that have been used to elucidate .... [...].
	1.2	(3)	Several recent papers point out a very important field observation ....
	1.3	(3)	(2 parenthetical citations)
	2.1a	(4-5)	This is in contrast to the first-generation ... [...].
	3.1b	(6)	This paper compares ....
	M	(7)	Then, using the field data as a basic geometric constraint, ...
NS-28	1.1	(1)	Models proposed for the reactivation of faults () indicate ... >
	1.2	(1)	and that there is an intimate association between fault reactivation and ....
	1.3	(2-4)	These ideas are ... compatible with the conclusions drawn from ... [...].
	2.1a	(5-10)	It is argued that .... [...]. It is suggested that .... [...]
	3.3	(11)	The paper begins with a brief discussion of the ideas ... followed by ....
NS-29	1.1	(1)	During the analysis ... the assumption is frequently made ....
	1.2	(2-3)	Although ... one of analytical convenience, the property of .... [...].
	2.1b	(4-5)	The application of this assumption to ... imposes severe limitations .... [...].
	3.1a	(6)	This paper examines .... [...].
	3.3	(7-8)	Once these ... geometries are defined ... attempts are made .... [...].
NS-30	1.1	(1)	In his seminal publication on oolite deformation ... >
	1.2	(1)	Cloos () suggested that crinoid stems could be used to ....
	1.3	(2-3)	He recognized that .... [...].
	2.1a	(4)	In practice, however, these conditions are rarely satisfied ... ().
	2.1b	(5)	Two sources of potential error in the simple two-dimensional analysis ....
	1.3	(6-13)	First, ... (). Second, ... (). [...].
	3.1b	(14-16)	In this contribution, two new methods are presented ....
	M	(17)	The three-dimensional strain is claculated from measurements of ....
	3.2	(18)	Two advantages of these new methods over that developed by Spratt () are ....

1. ... indicates text omissions.
2. [...] indicates sentence omissions.
3. () indicates citation omissions.
4. > indicates next clause begins a new STEP.
5. B Background Informat
6. M Method Step

APPENDIX B-2

Outline Structure of PAKISTANI RA Introductions

RA NO.	MOVES	Ss	SIGNALS (my emphases)
PAK-01	1.1	(1)	The Warsak granites are amongst the earliest recognised ....
	1.3	(2-3)	Ahmad et al., () mapped these granites ... while Kemp () presented ... [...].
	3.1b	(4)	In this paper, we use ... >
	2.1a	(4)	irrespective of their peralkaline ... character, >
	3.1b	(4-6)	are a typical example of .... [...].
PAK-02	1.1	(1)	Heavy minerals are commonly used ....
	1.2	(2)	This technique was first applied ....
	2.1b	(3)	Subsequent studies, however, ignored the heavy minerals ....
	1.3	(4)	With the availability ... it is now possible ....
	3.1b	(5-6)	In this paper, we present .... [...].
	3.2	(7)	Sandstone constitutes a major proportion of ....
	M	(8)	For the purpose ... ten sandstone samples were selected deom ....
PAK-03	1.1	(1)	The Patala Formation is the youngest Palaeocene formation exposed in ....
	3.1b	(2)	The present study is confined to the exposures ....
	B	(3-5)	In this area, the formation .... [...].
	1.3	(6)	[The] Only pervious ... study ... is by Rashid et al., () >
	2.1a	(6)	but they misunderstood ....
	1.3	(7-8)	General ... studies ... done by Ghauri et al., (). Meissner et al., () described ....
	3.1b	(9)	The present study deals with ....
	3.2	(10)	No coal association is present ....
PAK-04	1.1	(1-2)	The Main Boundary Thrust (MBT) is a regional lineament .... [...].
	1.3	(3-6)	A diverse assemblage of structures is reported .... [...].
	1.2	(7-9)	Recently, we have started a programme of reinvestigation .... [...].
	3.1b	(10)	In this paper, we present data on ... >
	2.1b	(10)	which have not been previously recognized, and which ... represent ....
PAK-05	B	(1-6)	Northern Pakistan is characterized by the presence of two .... [...].
	1.2	(6-7)	The Chilas complex comprises .... These rocks may partly represent ....
	1.3	(8-11)	....
	3.1b	(12-13)	Based on a study ... a summarised ... account ... is presented in this paper. [...]
PAK-06	1.1	(1-2)	The Shewa-Shabazgarhi complex is .... has been frequently investigated ....
	1.3	(2-9)	Coulson () who described .... Martin et al., () .... Several other workers .... [...].
	3.1a	(10)	The present study was carried out to map and perform >
	2.1d	(10)	further petrographic and geochemical study of the complex >
	3.1a	(10)	in order to determine ....
	M	(11)	Samples were prepared and analyzed for ....

1. ... indicates text omissions.
2. [...] indicates sentence omissions.
3. () indicates citation omissions.
4. > indicates next clause begins a new STEP.
5. B Background Information
6. M Method Step

RA NO.	MOVES	Ss	SIGNALS (my emphases)
PAK-07	1.1	(1-2)	Carbonatites are typically surrounded by ....
	1.3	(2)	Although many authors have made [sic] extensise studies ... >
	2.1b	(2-4)	but [sic] the process is still not well understood .... [...].
	3.1a	(5)	To understand the process ... samples are [sic] collected from ....
	3.1b	(6)	This paper presents ....
	3.2	(7)	The reverse changes in chemistry, in contrast ... correlate with ....
PAK-08	B	(1-3)	The early detritus shed by .... [...].
	1.1	(4)	The molasse sediments ... have been the focus of multidiscipliarry studies >
	1.3	(4)	including magnetostratigraphy (), biostratigraphy (), lithostratigraphy (), & ....
	2.1b	(5)	Most of these studies were [sic], however, concentrated on ... whereas little informations [sic] are available regarding ....
	B	(6-11)	The Kamlial Formation .... [...].
	2.1b	(12-13)	The Kamlial Formation ... has been devoid of [sic] any detailed ... studies. [...].
	3.1b	(14-15)	This study is [the] first of its kind and will deal mainly with .... [...].
PAK-09	B	(1-6)	The NE-SW rending Gandghar Range is located .... [...].
	1.3	(7)	Hylland et al., () have described ... the relationships ....
	3.1a	(8)	This paper is an attempt >
	2.1d	(8)	to extend the same relationship to the rocks of the northern Gandghar Range.
PAK-10	1.1	(1)	The term Pab Sandstone was introduced by .... [...].
	1.3	(2-5)	Williams () designated ....
	1.2	(6-7)	The formation is widely developed in the studied area .... [...].
	2.1a	(7)	however, in the studied areas, stratigraphic position ... is as under: ....
	3.1a	(8-9)	The present paper is intended to describe .... [...].
PAK-11	1.1	(1)	The Stratigraphic Committee of Pakistan subdivided the Siwalik Group ... >
	1.2	(1-3)	among which the ... Formaiton is not recognised in Baluchistan. Here, ... [...].
	1.3	(4)	The formation has been interpreted () ...
	3.1b	(5-6)	The present paper is based on .... New proposals are made and ....
PAK-12	1.1	(1)	A ... part of ... is characterised by ... which define an alkaline province ....
	1.2	(2)	The various igneous complexes of the province include .... [...].
	2.1b	(5)	Hitherto, no extrusive equivalents of ... have been reported ....
	3.1b	(6-8)	One of us (SRK) has recently carried out .... We report closely spaced .... [...].
	3.2	(9-10)	We consider that the acid volcanics reported here are extrusive .... The occurrence of ... has important implications for ....
PAK-13	1.1	(1-3)	A corroded feldspar ... was first described by .... [...]
	1.2	(4-5)	The role of deformation ... was first recognised by ().
		(5)	Several later workers () pointed out the significance of deformation in ....
	1.3	(6-7)	Indeed deformation is considered to be .... [...].
	3.1b	(8)	In this paper, we present ....
PAK-14	1.1	(1)	The Ambela Granitic Complex (AGC) ... has been a [sic] subject of ....
	1.3	(2)	Detailed petrographic accounts ... have been included in several papers ().
	2.1b	(3)	An important component ... so far undescribed, however, is the ....
	3.1b	(4-5)	In this paper, we present .... An attempt is made ....

1. ... indicates text omissions.
2. [...] indicates sentence omissions.
3. () indicates citation omissions.
4. > indicates next clause begins a new STEP.
5. B Background Information
6. M Method Step

RA NO.	MOVES	Ss	SIGNALS (my emphases)
PAK-15	B	(1-8)	....
	1.1	(9)	Since Oldham, many geologists have studied ....
	1.3	(10-11)	Oldham () and Davies () proposed .... Williams () proposed ....
	3.1b	(12-13)	Based on the study of ... the author herein proposes that .... [...].
	3.2	(14-16)	The author supports the HSC () in naming .... [...].
PAK-16	1.1	(1-8)	Post-Siwalik ... sediments ... have attracted the attention of (). [...].
	1.2	(9)	It is very likely that ....
	1.3	(10)	The lake itself might have formed ... as reported by Burbank () ....
	2.1b	(11)	The extent of a major lake ... is yet to be studied.
	3.1b	(12)	Present studies [sic] are confined to the identification of ....
	M	(13-14)	For this purpose, ten samples from .... Five samples from ....
PAK-17	B	(1-4)	....
	1.1	(5-8)	The Waziristan igneous complex .... Some ... investigations ... in the past. [...].
	1.2	(9)	Thus, it can be inferred that the Waziristan ... complex was ... emplaced ....
	1.3	(10-15)	This time of emplacement is similar to that of Bela () ... () ... (). [...].
	2.1b	(16-17)	So far, the ... complex has been labelled (), neglecting the significance of .... Such an association is, however, not very typical of ....
	2.1a	(18)	Rather, it is indicative of ....
	3.1a	(19)	The main object of our present work ....
	M	(20-22)	Samples from ... were collected for this purpose. [...].
PAK-18	1.1	(1-2)	Palaeozoic phosphate occurrences ... first discovered by .... [...].
	1.3	(3-12)	Significant contributions ... have been by a number of workers. [...].
	1.2	(13-14)	Recent advances in phosphate geology ... have [sic] made it easier to understand .... A well-defined terminology ... which can act as a tool ....
	3.1b	(15)	In the present paper, an attempt has been made to ....
PAK-19	1.1	(1)	The Ghazij Formation has been attracting the attention of geologists ....
	B	(2-9)	Coal has been mined from .... [...].
	1.3	(10-12)	The formation was initially mapped by .... [...].
	3.1a	(13)	The present paper is an attempt to ....
PAK-20	B	(1-2)	The Chilas complex represents .... It extends ....
	1.1	(3)	The field relationship ... have been described by several workers ().
	1.3	(4-8)	Majority of the rocks correspond to .... [...].
	1.2	(9-10)	The rocks were considered of ... by earlier workers. [...].
	1.3	(11-18)	Small to large masses of .... [...].
	3.1a	(19)	The aim of the present study is to present ....
PAK-21	B	(1-4)	The northern margin of the Indian plate .... [...].
	1.1	(5)	In the Swat Valley, a stratigraphic sequence ... was recognized by ().
	1.2	(6)	The Swat gneisses, part of a belt of ... lesser Himalas () .... [...].
	1.3	(7-8)	These rocks are .... The gneisses and overlying rocks form ... ().
	2.1a	(9-10)	... were previously considered .... Detailed investigations ..., however, ...
	3.1b	(11)	This requires a reinterpretation of the available data.
	3.2	(12-20)	Reconnaissance visits to ... confirm the extent of ....

1. ... indicates text omissions.
2. [...] indicates sentence omissions.
3. () indicates citation omissions.
4. > indicates next clause begins a new STEP.
5. B Background Information
6. M Method Step

RA NO.	MOVES	Ss	SIGNALS (my emphases)
PAK-22	1.1	(1-2)	The Malakand granite is one of the well known .... Several workers have ....
	1.2	(3)	The granite has intruded gneisses ... and metasediments of possible ... age ().
	1.3	(4-9)	The Malakand granite is an oval shaped body which covers .... [...].
	2.1b	(10-11)	The contact between ... is sharp, but ... can only be distinguished .... [...].
	3.1b	(12)	We present here a detailed map and eptrography of ....
PAK-23	1.1	(1)	In northern Baluchistan ... shows evidence of widespread volcanic activity.
	1.2	(2-4)	The limestones ... retain tell-tale signs of having been altered from .... [...]
	3.1b	(5)	In this paper, the petrography of ... is briefly discussed.
	B	(6-16)	......
PAK-24	1.1	(1)	The Chilas complex ... is probably the largest single mass of its type ....
	1.2	(2)	It holds a significant geological position ....
	1.3	(3-6)	.....
	3.1a	(7)	The present study is a >
	(2.1d)	(7)	further attempt to elaborate ....
	M	(8-13)	......
PAK-25	1.1	(1)	The Main Mantle Thrust (MMT) marks the convergent plate junction ....
	1.2	(2-3)	The origin and tectonic evolution ... attributed to .... The MMT zone is ....
	1.3	(4-9)	This zone in Swat and Kohistan comprised .... [...].
	3.2	(10)	Beside Shangla in Swat, blueschist facies were found by the authors ....
	3.1b	(11)	This newly found occurrence is described in detail in this paper.
PAK-26	1.1	(1)	In recent years, shear waves have been commonly used in seismic work ....
	1.2	(2)	These waves ... respond differently to ....
	1.3	(3)	For example, porosity of a rock ... () ... () ....
	2.1d	(4-5)	This differential behavour of Vs is of great significance .... The Vp/Vs ... is likely to provide an invaluabel tool ....
	3.1b	(6)	The emphasis in this paper is on ....
	M	(7-9)	For that [sic] study, the LUST ... data are taken into account .... [...].
PAK-27	1.1	(1-2)	The geology of Mingora is dominated by .... [...].
	1.2	(3)	The suture zone has been depicted as a region of ... >
	2.1b	(3-4)	however, no direct evidence ... has been recorded ....
	3.2	(5-6)	Present studies identify .... These findings will require major revision ....
PAK-28	1.1	(1-2)	Rocks of Shergarh Sar area ... have been distinguished into .... [...].
	1.3	(3-5)	According to Shah () .... [...].
	1.2	(6-8)	These are of great significance .... [...].
	3.1b	(9)	In this paper, the general field ....
PAK-29	1.1	(1-3)	The Chilas complex ... is a stratiform lopolith .... [...].
	1.2	(4-5)	Megascopically identifiable coronas occur in several places ....
	1.3	(6-10)	Olivine coronites were briefly described from Chilas by .... [...].
	3.1b	(11)	In this paper, we present an account of ....
	M	(12)	Several dozen thin sections have been performed ....
	?	(13)	Details of pahse chemistry will be presented in joint papers with B.F. Windley.
PAK-30	B	(1-4)	Syenites, quarts-syenites and granites are the major rock types .... [...].
	1.3	(5-7)	The region was first geologically investigated by .... [...].
	1.2	(8)	East and west of the complex, there are abundant occurrences of ....
	3.1a	(9-10)	This paper presents a detailed account of ....
	M	(11-12)	One hundred and twenty hand specimens were cut .... [...].

1. ... indicates text omissions.
2. [...] indicates sentence omissions.
3. () indicates citation omissions.
4. > indicates next clause begins a new STEP.
5. B Background Information
6. M Method Step

APPENDIX C-1

Outline Structure of Native RA Discussions

RA NO.	MOVES	Ss	SIGNALS
NS-01	1.1	(1-6)	Tolbachite contains ....
	2.1	(7-10)	Six examples of ... are given in Table 2. [...].
	2.2	(11)	The observed ... distances ... are close to the analogous value ... indicating that ....
	2.1	(12)	The observed ... distances ... lie in the range ... as compared with ...
	2.5	(13)	The wider range of ... is similar to that observed in ... >
	2.1	(14)	Note also that the ... apical distances are generally shorter ... than in ... ;>
	3.3	(14)	it will be interesting to see ... if the presence of ....
NS-02	1.1	(1-3)	The experimental data presented here ...
	1.2	(4-5)	Estimates of the time taken ... can be made using .... [...].
	2.1/2.2	(6)	Calculations using the values ... suggest that transformation of ...
	2.5	(7)	These estimated values ... are consistent with the reported ... values .... [...].
	2.2	(8)	That would suggest that ...
	2.3	(9-10)	Murowchick and Barnes () suggested that ...
	2.1	(11)	A half life ... estimated from the above data ... is ... whereas at ....
	2.5	(12)	These half lives show a consistency with the proposal of ... ().
	3.3	(13)	Again, these figures should be used with caution, taking note of the limitations ....
	2.5	(14-17)	It is, however, kinetic factors and not thermodynamic stability that ensure ....
	2.4	(18)	Furthermore, the suggestion by Fleet () ... implies minimal diffusion ....
	3.1	(19-24)	A nucleation model is in agreement ...
	3.2	(25-27)	Christian () summarized .... [...].
NS-03	1.1	(1-11)	Our experimental procedure involves three assumptions .... [...].
	1.2	(12-19)	Morse () provided .... [...].
	2.1/2.2	(21)	We produced strong resorption textures ....
	2.3	(22-26)	Previous studies have determined .... [...].
	2.1	(24-26	Because ... we constructed Figure 6 in order to evaluate .... [...].
	2.5	(27)	A model calculated for ... rather than ... provides a more conservative estimate ...
	2.1/2.2	(28-33)	The details of the calculation of the curves .... [...].
	3.1	(34)	Our experimental results provide a basis for interpreting .... [...].
	2.1/2.2	(36-48)	The lava in Figure 1 is strongly porphyritic .... [...]. One analysis of ... >
	2.5	(49-54)	Unfortunately, it is nearly impossible to ....
	3.1	(55-64)	Perhaps the nucleation of euhedral ... was in response to ... [...].
NS-04	1.1	(1)	Having established that LSQ is an appropriate methodology for ....
	2.1	(2-3)	An important observation .... [...].
	2.2	(4)	As a consequence, the main contribution ... is likely to come ....
	2.4	(5)	It is for this reason that Engi and Lieberman () ... reached the erroneous conclusion ....
	2.5	(6-8)	The formally correct way to proceed .... [...].
	3.1	(9)	If entropies ... the LSQ logic is still appropriate ...
	3.2	(10-11)	We conclude .... [...].
NS-05	2.1/2.2	(1-6)	Table 3 lists mean dielectric constants .... [...].
	2.3	(7)	The agreement between the observed ... and ... calculated ... is excellent .... >
	2.1/2.2	(8-14)	The slightly larger deviation ... >
	3.1	(15-17)	This group of beryllates, borates and ... form a class of .... [...].

1. ... indicates text omissions.
2. [...] indicates sentence omissions.
3. () indicates citation omissions.
4. > indicates next clause begins a new STEP.

RA NO.	MOVES	Ss	SIGNALS
NS-06	2.1/2.2	(1-7)	It is apparent that impurities ... may have influenced .... We suppose that ....
	2.5	(8)	In fact, both processes could have occurred.
	3.1	(9-10)	Chemical ... are important aspects of ... etch tunnels formed only in ...
	3.3	(11-12)	Additional experiments are needed .... If growth of etch tunnels occurs ....
	2.1/2.2	(13-16)	Longer tubes were produced by longer experiments ....
	2.4	(13-27)	Healing ... is consistent with the experiments of ... [...].
	3.3	(28-33)	If Hacker and Christie () are correct ... then some of the questions unanswered by this warrant further investigation. [...]
NS-07	1.1	(1)	Having established that our calculations reproduce ... we can use the results ....
	2.1	(2-3)	The assignment of the peak at ... seems reasonable .... [...].
	2.2	(4-6)	We assign this to .... [...].
	3.3	(7-8)	Clearly it would be desirable to perform calculations on larger .... [...].
	3.1	(9-11)	The species yielding ... might differ .... The absence of ... indicates .... [...].
	2.1	(12-13)	The calculated Al and F deshieldings of ... are only .... [...]
	2.3	(14-16)	We can calibrate our calculated deshieldings by comparing .... [...].
	2.5	(17-18)	On the basis of this comparison ... we expect the ... calculations to .... [...].
	3.1	(19-24)	Incorporation of thc ... [...]. Distinguishing ... would certainly be difficult.
	3.4	(25-27)	Although ... we nonetheless feel that ... can be confidently obtianed [...].
NS-08	1.1	(1-2)	Structural details ... are complicated ....the adjustments are subtle and ....
	2.1/2.2	(3-19)	As anticipated, Fe-bearing ... are larger than .... [...].
	2.3	(20)	From past experiences () ....
	2.1/2.2	(21-30)	Although ... we consider the agreement ... quite encouraging. [...].
	2.3	(31)	It is perhaps noteworthy that ... frequency of ... is close to ... () and ... ().
	3.1	(32)	In general, the agreement seems to be best where ...
C	3.4	(33-38)	1. For simple amphiboles ... [...].
	3.1	(39-40)	By all indications, the differences ... are specifically related to local variations .... The single most important factor influencing the position ....
NS-09	2.1	(1-3)	For an H1 hydrogen atom, ... Table 2 gives the coordinates and .... [...].
	2.2	(4)	Presumably this situation would pertain ....
	2.4	(5)	The ordering approximates ... ().
	2.1/2.2	(6-35)	Figure 2 is a map of the energy .... [...].
	3.1	(36-37)	With their ... low energies, group-III orderings could be very important ....
C	3.4	(38-45)	1. ... 2. ... 3. ...
	3.1	(46-50)	With regard to hydrogen bonding, it is tempting to consider ...
NS-10	2.1	(1-3)	From synthetic ... Na yields a GDC of .... [...].
	2.3	(4)	Jaffe's average value ... but it is not clear how this figure was derived.
	2.1/2.2	(5-11)	Because GDCs ... additive, some difference ... is to be expected ... [...].
	2.3	(12)	For the feldspar data-set of Gumer and Bloss (), the least-sqaures method ....
	2.1/2.2	(13-36)	A data-set of ... yielded a GDC of .... [...].
	2.3	(37-38)	The new ... pyroxene described by () and () also contains .... [...]
	3.1	(39)	Until more data becomes available ... average figure ... seem ... appropriate.
	2.1/2.2	(40-44)	Except ..., the GDCs listed in ... are applicable to all the major groups .... [...].
	3.1	(45-48)	Some of the variation may be ... This variation correlates ...
	1.1	(49-52)	The L-L law has a theoretical basis; it is expressed .... [...].
	1.3	(53-61)	Anderson () developed the L-L law to include .... [...].
	2.1	(62)	Thus the polarizability is ... related to ... and is directly proportional to ....
	2.2	(63-65)	This result suggests .... [...].
	2.3	(66-67)	Jaffe () listed the polarizability of a number of minerals .... [...].
	2.1/2.2	(68-74)	The simple oxides ... yield ... different polarizabilities ... [...].
	3.1	(75-77)	Consideration of electron overlap may also explain .... [...].
	3.4	(78-82)	The Gladstone-Dale constants ... [...]. Values determined ... [...].

1. ... indicates text omissions.
2. [...] indicates sentence omissions.
3. () indicates citation omissions.
4. > indicates next clause begins a new STEP.

RA NO.	MOVES	Ss	SIGNALS
NS-11	1.1/1.2	(1-3)	The possible source of ammonium in tuffaceos rocks ... [...].
	2.4	(4)	This point needs to be emphasized because ....
	2.5	(5)	Such data need to be questioned ....
	2.1/2.2	(6-17)	Unpublished data ... showed ... [...]
	3.1	(18)	The time scale ... a sequence of event ... is: 1. ... 2. ... 3. ... 4. ... 5. ...
	3.3	(19-20)	This sequence should be ragarded only as a simple working hypothesis .... [...].
NS-12	2.1/2.2	(1-6)	The Rb-Sr systematics of the Mt. Roe #1 paleosol indicate that .... [...].
	2.3	(7-8)	Recent whole-rock Rb-Sr data ... () yield a scattered .... [...].
	2.1/2.2	(9-10)	The similarity of the ... and the ... suggests that they both reflect ....
	2.3	(11-12)	The weathering profile is thought to have formed ... (). [...].
	2.1/2.2	(13-16)	The alkali metasomatism ... probably occurred in response to .... [...].
	3.1	(17-19)	The ... fluids must have contained .... The most likely source .... [...].
	2.1/2.2	(20-21)	The samples from ... have more complicated Rb-Sr systematics than ... [...].
	2.5	(22-23)	This age is identical ... (). [...].
	2.3	(24)	Filed evidence for hydrothermal modification ... was noted by ().
	2.1/2.2	(25-29)	Samples having lower ... do not conform to .... [...].
	3.1	(30)	The sediments ... likely source of ...
C	3.4	(31-37)	Three precambrian paleosols of different ages ... reflect resetting and .... [...].
NS-13	2.1/2.2	(1-16)	As noted above, the spacial relationship of the thucholite ... [...].
	2.5	(17)	However, phosphate minerals have not been reported ...
	2.1/2.2	(18-26)	Low Si and V contents are recorded .... [...].
	2.3	(27-29)	These two phases ..., and rhabdophane is recorded elsewhere ... (). [...].
	2.2	(30)	The high Th content ... suggests affinities ....
	2.4	(31-33)	However, the brockite described by () contains an excess of .... [...].
	2.2	(34-36)	The oxygen/metal atomic ratios close to 6 suggest a formula ... [...].
	2.3	(37-40)	Van Wambeke () reported ... and account by () .... In both cases .... [...].
	3.1	(41-44)	It is likely ... occurred on a very localized scale. This would explain .... [...]
NS-14	1.1	(1)	P-T fields of stability ... have been calculated according to ... ().
	2.1/2.2	(2-6)	The equilibria indicate that ... [...].
	2.3	(7)	It is possible, therefore, that the observed texture ... represents ... ().
	2.5	(8-12)	However, evidence such as ... indicates that ... [...].
	2.1/2.2	(13-19)	Both cores and rims have the same ... chemistry ... [...].
	2.3	(20)	Stoddard () observed the retrograde ...
	2.1/2.2	(21-27)	Staurolite is observed ... [...]
	2.3	(28-29)	The reaction of Wall & England () ... also is observed ... [...].
	3.1	(30)	All these factors support ...
	3.2	(31)	Such an interpretation is consistent ...
NS-15	1.1	(1-2)	If the model of Sides () ... is correct, the depth ... ranges from .... Regardless of what factors are the most important ... one would expect ... a ... variation.
	2.1/2.2	(3-6)	However, the total range ... shown by our samples is ... quite small. [...].
	2.3	(7-10)	The first detailed petrographic study ... was published by (). [...].
	2.4	(11)	Sides et al., claimed that ... but our ... examination does not support ...
	2.1/2.2	(12-16)	With the exception of two samples ... all our samples show .... [...].
	2.4	(17)	Tolman and Robertson () attributed ... but recent ... data suggest that ... [...].
	2.1/2.2	(18-21)	Rb-Sr dates for ... are ... younger than ... (). Bickford & Mose interpreted ....
	3.1	(22)	It seems quite reasonable that K-feldspar could have become ordered ... >
	3.2	(22)	and Abdel-Rahman & Martin () have recently documented just such a ...
	3.1	(23)	Therefore, we interpret ...
	3.3	(24)	Why the ordering did not proceed ... remains a mystery.
	3.1	(25-27)	An interesting subsidiary conclusion from our data concerns .... [...].
	3.2	(28)	This conclusion is supported by ...

1. ... indicates text omissions.
2. [...] indicates sentence omissions.
3. () indicates citation omissions.
4. > indicates next clause begins a new STEP.

RA NO.	MOVES	Ss	SIGNALS
NS-16	2.1/2.2	(1-13)	The importance of careful investigation of the background is illustrated in ...
	2.5	(14-30)	... interference cannot be avoided. ... another problem ... ... difficult ...
	3.3	(31)	Although ... the best way to deal with the problem ...
	2.1/2.2	(32-34)	Because the results ... are judged against ... [...].
	2.3	(35)	Barnes et al., () and Heinrich et al., () have clearly demonstrated that such ....
	2.2	(36-43)	The present microprobe results also suggest ... [...].
	2.3	(44-51)	A detailed discussion .... a variety of procedures have been proposed ... [...].
	2.1	(52-54	Detection limits reported in the present study .... [...].
	2.2	(55-57)	As expected, they show that .... [...].
	2.4	(58)	However, the results agree with ... reported by (). [...].
	3.1	(59)	Thus, although ... they are meaningful analytically.
	3.2	(60-61)	Bence et al., () have likewise found ... In their studies, ...
C	3.4	(62-65)	We conclude that the trace-element ... can be readily carried out .... [...].
NS-17	1.1	(1-4)	The hydrothermal material dredged from ... is part of a ... deposit. [...].
	2.1/2.2	(5-14)	Elemental analyses ... yield values for ... that are typical .... [....]
	2.3	(15)	Tivy & Delaney () proposed a similar scenario .... [...].
	2.1/2.2	(16-17)	In contrast to ... a complete neutral spectrum ... [...].
	2.3	(18-25)	Herzig et al., () suggested that ... [...].
	3.1	(26)	We therefore concur with other workers that ....
NS-18	1.1/1.2	(1-5)	TL spectra of minerals exhibit changes as a result of ... [...].
	2.1	(6-8)	Calcite is a bright TL phosphor which emits strongly .... [...].
	2.2	(9-15)	These differences are interrpreted ... [...].
	1.1	(16-18)	Studies of ... () have demonstrated .... [...]. One obvious reason for this is ....
	2.1	(19-29)	The samples of green fluorite ... exhibited .... [...].
	2.2	(30-31)	... the roles played by ... appear complex and they may be varied .... [...].
	1.1	(32-33)	Zircon is a common component ...
	2.1	(34-37)	The emission spectra of two samples ... show broad features .... [...].
	2.2	(38-41)	This ... feature is characteristic of ... and may be related to .... [...].
	3.1	(42)	This work has served to undeline ...
	2.1/2.2	(43-44)	In contrast ... TL emissions ... are dominated by .... [...].
	2.3	(45-49)	In contrast ... the samples of plagioclase studied by ... have shown no .... [...].
	3.1	(50)	There is some evidence ... that RE ions rarely if ever occur ...
C	3.4	(51-53)	The examples given above have served to .... [...].
NS-19	2.1	(1-13)	The compositions of ... are shown in Table 4. [...].
	2.2	(14-17)	The fact that most inclusions are equant ... suggests that they are .... [...].
	2.3	(18-20)	The range of ... values ... fall within the span .... These data strengthen ...
	2.1/2.2	(22-24)	The ... sample ... contains higher .... Thermometric data yields ....
	3.1	(25-26)	These results show that .... They also point to ....
NS-20	2.1	(1-5)	The Vangorda orebody has undergone .... [...].
	2.2	(6-9)	These textures indicate .... [...].
	2.1/2.2	(10-24)	Breccia textures and ... are localised in .... [...].
	2.5	(25)	To date, a full appreciation of the role ... has not been assessed.
	3.1	(26)	However, ... indicates that ... likely played a role ...
	2.5	(27-30)	The precise effect ... are unknown ....
	3.1	(31)	The deformation of ... may be expected to ...

1. ... indicates text omissions.
2. [...] indicates sentence omissions.
3. () indicates citation omissions.
4. > indicates next clause begins a new STEP.

RA NO.	MOVES	Ss	SIGNALS
NS-21	1.1/1.2	1-3)	Chemically, BD83 is a ... However, the texture ... are unlike those .... [...]
	2.1	(4)	It is noted above that ... BD83 is texturally similar to ....
	2.2	(5)	To suggest that BD83 derives from ... is to enter a debate ....
	2.3	(6-9)	[...].
	2.2	(10-12)	If a convincing case is to be made for .... [...].
	3.1	(13-15)	It is suggested that these features ... () provide strong ... evidence for .... There is of course incontrovertible evidence ....
	3.4	(16-17)	The minerals in ... are highly unusual and ... (). Low-temperature alterations has lead to breakdown of ....
NS-22	2.1	(1-6)	In contrast to the case of Pb(II), titration of ... shows no distinct .... [...].
	2.2	(7)	The extent of this and related phases is uncertain ....
	2.3	(8-9)	Proposed compositions ... range from () to (). Donaldson () has prepared ....
	2.2	(10-11)	The discrepancy ... is attributable to .... The true formula ... is ....
	2.1	(12)	Solid phases produced ... are mixtures of ....
	2.2	(13)	As indicated previously, an increase in ... extends the range of stability ....
	3.1	(14)	This may have great significance with respect to ....
	2.1	(15-17)	A stability constant for abhurite ... has been derived .... [...].
	2.5	(18)	The result is clealry more accurate than the former value reported () ....
	2.1	(19-26)	These new quantities have been used .... [...].
	2.2	(27-29)	Increasing salinity and reduction in pH give rise to conditions that .... [...].
	2.3	(30-32)	Basic tin(II) salts ... have been reported .... [...].
	2.1/2.2	(33)	The compound $SnCl_2$ does not appear on the stability field diagram ....
	3.1	(34)	Thus reports of $SnCl_2$ ... recovered from ...are probably spurious .... [...].
NS-23	2.1/2.2	(1-11)	From the microtexture observed in ... it can be seen that .... [...].
	2.3	(12-13)	Many authors () have suggested that .... These authors also suggested that ....
	2.4	(14)	These ideas are in agreement with what is observed in the Renstrom deposit.
	2.5	(15-16)	However, the meta-dolomite ... appears to have been stronger than .... It indicates ....
C	3.1	(17-20)	Sulphide mylonites ... have formed by .... [...].
	3.2	(21-23)	This agrees with that proposed ... by authors such as (). [...].
NS-24	2.1/2.2	(1-24)	The multiple corona textures described above formed .... [...].
	2.3	(25)	Inward collapse of ... is thought to have produced ... ().
	3.1	(26)	We suggest that this may also have promoted ....
	3.2	(27)	This is supported by detailed compositional mass balance anlysis ... () ....
	2.1/2.2	(28-42)	The development of ... is interpreted to post-date .... [...].
	3.1	(43-45)	In conclusion it can be said that .... [...].
NS-25	1.1/1.2	(1-23)	The origin of garnets in granitic rock ... has long been problematical ....
	2.1/2.2	(24-25)	Garnets formed as ... precipitate .... Many ... garnets have very high ... >
	2.3	(25)	a feature that Baldwin and von Knorring () consider is only achieved ....
	2.5	(26)	However, a few garnets from ... also have high ... contents ....
	2.3	(27-31)	() also noted crystallisation temperatures as low as .... [...].
	3.1	(32-39)	Thus, those chemical ... indicate that ....
	3.2	(40-42)	A similar model ... was proposed by Harrison () .... [...].
	3.1	(43)	Garnets ... have much lower ... suggesting that ....
	3.2	(44)	A similar trend was observed by ....
C	3.4	(45-56)	....

1. ... indicates text omissions.
2. [...] indicates sentence omissions.
3. () indicates citation omissions.
4. > indicates next clause begins a new STEP.

RA NO.	MOVES	Ss	SIGNALS
NS-26	1.1	(1-16)	Several previously reported observations of ... indicated that .... [...].
	2.1/2.2	(17-21)	The new data presented here imply that .... [...].
	2.3	(23-25)	To understand ... we compare the results .... Vaughan & Coe () found .... [...].
	2.5	(26)	Thus, although the rheology ... has not been fully characterized, it is not compatible with frictions or with ... of either olivine or spinel.
	2.2	(27-28)	The most reasonable interpretation is that .... [...].
C	3.1	(29-33)	This investigation confirms that ... () ... and further shows that .... [...].
	3.2	(34)	Iidaka & Suetsugu () provided evidence that ....
	3.4	(35-37)	Microstructures of ... are essentially identical to those of ... and we expect that the rheology and accoustic emissions (seismic) characteristics ... will be similar. [...].
NS-27	1.1	(1-2)	Most of the modelling of ... assumes .... They do not ... allow for ....
	1.2	(3-7)	Wojtal () has given a ... field description of ... but did not address .... [...].
	2.1	(8-9)	One of the most striking features of the experiment .... [...].
	2.2	(10)	If ... the assumption made ... would be reasonable ....
	2.3	(11-14)	Both Reches () and Gapais et al., () demostrated that .... [...].
	2.1	(15)	In our field example, the angles are typically ....
	2.2	(16-18)	It may well be that the existence of .... [...].
	3.3	(19-21)	It would be interesting to generate analogue models .... [...].
	3.1	(22-23)	As such, this suggests .... [...].
	3.3	(24-25)	If the faults were less ... different ... conditions would be required and .... [...].
C	3.4	(26-32)	By combining and synthesizing information .... it is possible to model a system .... [...].
NS-28	2.1/2.2	(1-5)	The composite crystal veins discussed earlier provide evidence to indicate ....
	2.3	(6-10)	The movement of tectonically driven fluids ... has been considered by (). [...].
	2.1/2.2	(11-13)	As these folds amplify .... Multiple layers ... indicate that .... [...].
	2.2	(14-15)	It is suggested that the process ... is directly analogous to .... [...].
	3.1	(16-20)	It follows that during folding there will be .... [...].
C	3.4	(21-25)	The evidence ... indicates that .... [...].
NS-29	1.1/1.2	(1-6)	Isotrend line analysis is capable of detecting .... [...].
	2.2/2.2	(7-8)	Although only a few structure maps ... it is already apparent that .... [...].
	2.5	(9)	In a strict sense, line-length balancing ... is a theoretically unsound technique ....
	3.1	(10)	Although the isometric model is an idealized one, its predictions may ....
	3.3	(11)	The model requires a careful consideration ... () ... () ... ().
NS-30	1.1	(1)	The methods presented in this paper are simple extensions of ....
	2.1/2.2	(2-9)	When applied to crinoid ossicles ... the methods produce results that are internally consistent .... The significant scatter and probable error ranges ... are .... [...].
	2.4	(10-14)	The methods described here have several advantages over ... technique developed by (). First, ... Second, ... Third, ...
	2.3	(15)	Spratt showed that the c-axis cannot be determined uniquely if it is ....
	2.5	(16-17)	However, for ossicles ... the c-axis cannot be determined unambiguously. [...].
	3.1	(18)	The Rf/ø ... methods, on the other hand, are not bound by ... these restrictions ....

1. ... indicates text omissions.
2. [...] indicates sentence omissions.
3. () indicates citation omissions.
4. > indicates next clause begins a new STEP.

APPENDIX C-2

Outline Structure of PAKISTANI RA Discussions

RA NO.	MOVES	Ss	SIGNALS
PAK-01	1.1	(1-5)	Granites are found in almost all the major tectonic settings .... [...].
	1.2	(6-7)	Obviously, for a precise determination of ... a two-fold approach is required .... [...].
	2.1	(8)	... it is now possible to assign a Late Palaeozoic age to the Warsak granites ....
	2.2	(9-10)	... one is compelled to relate .... There is a possiblity that ... is equivalent to ....
	2.3	(11-12)	It has to be noted that Kemp () pointed out .... The close association of ... is a characteristic of ... as described by () and ().
PAK-02	1.1/1.2	(1-10)	Although the heavy mineral assemblage appears .... [...].
	2.1	(11-13)	Of all the heavy minerals found in ... garnet and amphibole are ... important .... [...].
	2.2	(14-15)	A greater abundance of garnet ... suggests that .... [...].
	2.1	(16)	These two minerals, however, do not appear simultaneously; ....
	2.2	(17)	This may be due to differences ....
	2.1	(18)	Amphibole in the Kihistan arc is ... found in ....
	3.1	(19-20)	Appearance of the amphibole at the base ... would record a metamorphic event .... The appearance of pyrobe-rich garnet in the uppermost ... suggests exposure ....
PAK-03	1.1/1.2	(1-3)	The Patala Formation consists of fauna such as .... [...].
	2.1	(4-6)	The pebbles in strata ... are in general rounded. [...].
	2.2	(7-14)	This textural ... and compositional maturity ... suggests their ... (). [...].
	2.1	(15)	The sediments of this formation are not bioturbated.
	2.2	(16-20)	The conditions ... were hospitable .... The absence ... could then be considered ....[...]
	2.4	(21-23)	Rashid et al., () mistakenly considered .... [...].
	2.5	(24)	In reality, the sequence is transgressive upward.
	3.1	(25-29)	The Patala Formation depicts .... The most pronounced change .... [...].
PAK-04	2.1	(1-4)	Whereas the recognition of faults ... has been a simple matter ... [...].
	2.2	(5)	Our interpretation ... have [sic] been portrayed in Fig ....
	2.4	(6)	We, however, do not believe in the entirely reverse sense of movement of ....
	2.5	(7)	The shallow ... dip of these faults ... would favour a normal sense of movement.
	3.1	(8-10)	We interpret that .... This led to initialtion of .... [...].
C	3.4	(11-14)	.....
PAK-05	2.1/2.2	(1-9)	Systematic variation ... suggests that .... [...].
	2.3	(10-13)	In the plutonic rocks from ... () .... Garcia () has reported .... [...].
	2.4	(14)	However, a complete lack of ... do not typify ... a Alaskan-type.
	2.3	(15-19)	The Duke Island Alaskan-type .... [...]. Irvine () suggested that .... [...].
	3.1	(20-27)	Such a situation may also have existed in .... [...].
	3.2	(28-29)	The Chilas complex ... is also considered calc-alkaline ... () .... [...].
	3.1	(30)	Thus, ... the Tora Tigga complex may be related to ....
	3.2	(31)	Luhr & Carmichael () regard ... as spinel has probably played a role in ....
	3.1	(32)	The Tora Tigga ... may represent such a example of ....

1. ... indicates text omissions. 3. () indicates citation omissions.
2. [...] indicates sentence omissions. 4. > indicates next clause begins a new STEP.

RA NO.	MOVES	Ss	SIGNALS
PAK-06	2.1/2.2	(1-24)	It is obvious from the filed relationship that .... [...].
	2.3	(25-27)	This observation is in accord ... (). [...].
	2.1/2.2	(28)	A careful examination unravels that ... a feature indicating it to be ....
	3.3	(29-31)	Unfortunately, all the chemical data presented ... belong to .... [...]. In such a case the origin of ... nedds to be reconsidered for ....
	2.1/2.2	(32-35)	The most significant feature .... [...].
	2.3	(36)	Ahmad () has attributed the formation of ....
	2.4	(37)	Cataclasis is, however, generally referred to ....
	3.1	(38-39)	Therefore, as mentioned earlier, the growth of ... may be considered .... [...].
	2.4	(40-43)	One of the confusing aspects ... (). These authors ... considering only .... [...].
	2.5	(44-45)	Also ... has characters ... more representative of ... rather than .... In fact, ...
	3.3	(46)	Therefore, ... a careful examination is neded ....
	2.3	(47)	Several theories have been proposed ....
	3.1	(48-49)	The present study has confirmed .... [...]
	3.3	(50-51)	It is not very clear whether .... studies are needed to resolve these issues.
	3.1	(52-53)	It is appealing, however, to consider that ... has provoked .... [...].
PAK-07	1.1/1.2	(1-3)	The Na-pyriboles ... have compositions related to .... [...]. These trends, given by different authors ....
	2.1/2.2	(4-19)	Similar trend is present in .... [...].
	2.3	(20)	Similar reverse trends have been reported from ....
	2.1/2.2	(21-24)	In Koga, ... high Na/K ratio ... occurs, the possibility ... cannot be overruled.
	3.1	(25-30)	The study of ... suggests: 1) ... 2) ... 3) ... 4) ... 5) ... [...].
PAK-08	1.1	(1-4)	Molasse sedimentation .... [...].
	2.1/2.2	(5-10)	The very thick sandstones .... [...].
	2.3	(11-12)	According to Allen () and .... [...].
	3.1	(13-17)	The river system ... probably entered .... [...].
PAK-09	1.1	(1-5)	Since ... suggesting [sic] that .... [...].
	2.1	(6-9)	These faults have ... in common. Firstly, ... Secondly, ... And thirdly, ...
	2.2	(10-13)	These features suggest that .... [...].
	2.3	(14-18)	The rocks of ... are grouped into ... () .... [...].
	2.1	(19)	The rocks between ... are either very low in ... or ....
	2.2	(20)	It is, therefore, suggested that ....
	3.1	(21-27)	The Gandghar can be divided into .... [...]. The sequence ... suggest that ....
PAK-10	2.1/2.2	(1-2)	The Pab Sandstone ... is moderately to well-sorted .... [...].
	2.3	(3)	It has been argued () that ....
	2.5	(4)	The Pab Sandstone, on the contrary, behaves differently which may be ....
	2.1/2.2	(5-6)	Samples of ... are rich in .... [...].
	3.1	(7)	Therefore, on the basis of ... it may be suggested that ....
PAK-11	2.1/2.2	(1-6)	Environmental interpretations .... based on Miall's () work .... [...].
	2.3	(7)	The high proportion of ... resemble with [sic] ... model of Miall () and ....
	2.1/2.2	(8-11)	The occurrence of .... [...]. Se with mud ... an indication of ....
	3.1	(12)	Combination of ... reflect ... and indicate that ....
	3.2	(13-14)	During flood conditions ... () .... Plannar crossbeds ... ().
PAK-12	1.1	(1-12)	Whereas the external zone .... [...].
	1.2	(13-19)	All these igneous rock are [sic] subject of ... studies ... for several decades. [...].
	2.2/2.2	(20-22)	The volcanic nature of ... confirms .... [...]. We assign all the ... to ....
	2.3	(23)	It has to be noted that ... has been condiered by ... () ....
	2.2	(24-29)	This would imply .... There is a strong indication that .... [...].
	3.1	(30-31)	We suggest that .... [...].
	3.2	(32-33)	There have suggestions that .... [...].
	3.3	(34)	This [sic] is, however, not understood that [sic] why ....

1. ... indicates text omissions.
2. [...] indicates sentence omissions.
3. () indicates citation omissions.
4. > indicates next clause begins a new STEP.

RA NO.	MOVES	Ss	SIGNALS
PAK-13	1.1	(1-9)	Models explaining the formation of .... For example, ... [...].
	2.1/2.2	(10-13)	The myrmekites ... are characterised by .... [...].
	2.3	(14-16)	There are, however, some differences ... relative to ... reported by ().
	2.2	(17-18)	This suggests that .... Additionally, there is ... relationship ....
	2.3	(19-21)	The presence of ... has previously been suggested to .... [...].
	3.1	(22)	Thus, althoug there is little doubt ... the mechanism involded was ....
PAK-14	2.1/2.2	(1-9)	The megascale characteristics of ... show .... [...].
	2.3	(10)	These are thought to be related ... ().
	2.1/2.2	(11-15)	In Figure 1, ... trace elements ... are compared with .... [...].
	3.1	(16)	These features ... are comparable with .... suggesting that ....
PAK-15	1.1/1.2	(1-7)	The strata overlying the ... have been described as ... (). [...].
	2.1/2.2	(8-10)	The upper limit is .... [...].
	3.1	(11)	It is proposed that ....
	3.2	(12)	The lithology of ... () and ... () are very similar to ....
	3.3	(13-14)	Present studies clearly signify the need for more ... studies .... [...].
PAK-16	1.1/1.2	(1-7)	In the non-marine sedimentary basins, chlorites are derived from .... [...].
	2.1	(8)	The lake deposits of ... do not show any signs of ... metamorphism.
	2.2	(9-16)	Thus, in these deposits ... cannot be attributed to .... [...].
	3.1	(17-18)	Our present study reveals that .... Thus, it is inferred that ....
	3.3	(19)	A detailed study of ... is in progress.
PAK-17	2.1/2.2	(1-5)	The mineral composition of .... [...].
	2.3	(6-8)	In case of ... it has been shown by () that .... [...].
	2.1/2.3	(9)	In the studied ... is an obvious ... phase, indicating the same ... as the ... ().
	2.4	(10-11)	These features show a prominent contrast the ... (). [...].
	2.5	(12)	Such high pressure ... would be more likely at ....
	3.1	(13)	The spinels can provide useful clues ....
	3.2	(14-15)	According to Dick and Bullen (), spinels with ...
	2.1	(16-17)	The spinels from ... contain .... [...].
	2.2	(18-19)	Thus, it is suggested that these rocks cannot be .... [...].
	2.1	(20)	A prominent feature of ... is that ....
	2.3	(21-23)	An (90-100) is an important constituent ... (). [...].
	2.1/2.2	(24-26)	In the studied ... is commonly enclosed .... This feature also suggests .... [...].
	2.4	(27-28)	Such ... ratios ... further contradict .... This interpretation ... supported by ().
	2.3	(29-30)	The chemical composition ... reflects ... (). ... have been ... used for ... ().
	2.1	(31-34)	The ... from ... were similarly employed .... The ... from ... differ from .... [...].
	2.2	(35-36)	The low ... value of ... evince their ... and contradict .... Figure 8 shows ....
	2.3	(37-38)	The ... discrimination of Nisbet and Pearce () also supports .... [...].
	2.5	(39-40)	As the alkalic ... has been ruled out ... remains the only alternative .... [...].
	3.1	(41-42)	In view of these ... it is suggested that .... The ... position of ... indicates its ....
C	3.4	(43-48)	Present study ... provides evidences for .... [...].
	3.3	(49)	Further investigations ... are needed to elaborate ....
PAK-18	2.1/2.2	(1-3)	The petrological studies indicate that .... [...].
	2.1	(4-9)	Two phosphate horizons are noticed .... [...].
	2.2	(10-13)	These features indicate .... [...].
	3.1	(14)	The associated ... could have formed as ....
PAK-19	1.1	(1-2)	According to delata model .... Other characters include ....
	2.1	(3)	In sequences of ... the ... cycles are not very clear.
	2.2	(4-5)	These cycles may undoubtfully [sic] have been disturbed .... [...].
	3.1	(6)	It is proposed that ....
	2.1/2.2	(7-8)	The uppermost ... part again shows ... that suggest .... Apart ... represent ....
	3.1	(9)	It may be said that ....

1. ... indicates text omissions.
2. [...] indicates sentence omissions.
3. () indicates citation omissions.
4. > indicates next clause begins a new STEP.

RA NO.	MOVES	Ss	SIGNALS
PAK-20	1.1/1.2	(1)	Previous workers () have suggested three ... mechanisms .... a) ... b) ... c) ....
	2.1/2.2	(2-14)	The continuous variation and ... indicate an .... [...].
	2.3	(15-16)	Such a ... model is consistent with .... These may have disappeared ... ().
	2.1/2.2	(17-22)	As mentioned earlier, the occurrence of ... can be attributed to .... [...].
	2.3	(23-26)	Breman () ... found that .... [...].
	2.1/2.2	(27)	These evidence and the presence of ... indicate that ....
	2.3	(28-30)	This interpretation is sonsistent with .... [...].
	2.1/2.2	(31-33)	Majority of ... indicate .... Inclusions of ... have also been noticed .... [...].
	2.3	(34-36)	This interpretation is consistent with .... [...].
	2.1/2.2	(37-42)	Compositional plots ... indicate that .... [...].
	2.3	(43)	According to Jan (), ...
	3.1	(44-46)	All these features indicate that either .... [...].
	3.2	(47)	Jan () has put forward several views ....
	3.3	(48)	With the present limited data available, it is difficult to support ....
	3.1	(49)	However, the ... affinities ... suggest that its origin was ... related to ....
	3.2	(50)	This view is further corroborated by ... ().
PAK-21	1.1/1.2	(1-19)	A model ... is proposed. Temporal constraint ... is the 510-520my age .... [...].
C	2.1/2.2	(20-21)	Geochemical analysis of ... indicates .... Recent field work ... has revealed ....
	2.3	(22-23)	The parent rock were ... similar to basals from Greenland (). [...].
	3.1	(24-25)	Subject to ... these ... are evidence .... Taken together, the evidence suggests ....
	3.2	(26-29)	The extent ... has been traced .... The gneissic ... has a known extent (). Le Fort () has described .... [...].
	3.1	(30)	This account is strongly reminiscent of the Swat region.
PAK-22	1.1	(1)	The Malakand granites ... represent rocks of ....
	2.1/2.2	(2-33)	Based on ... the order of the appearance ... is .... [...].
	3.1	(34)	The present investigatio shows that ... have evolved through ....
	2.1/2.2	(35-36)	The Malakand granite has ... ratios .... The minimum limit of ... is ....
	2.3	(37-45)	The K/Rb ration ... however, is ... lower than that proposed by (). [...].
	3.1	(46-47)	The lack of deformation ... however, strongly supports the view .... In addition, ... supports the view that there is not any genetic realtionship between ....
PAK-23	1.1	(1-3)	The Bibai rocks indicate .... [...].
	2.1/2.2	(4)	The great thickness and ... of the Bibai ... suggest presence of ....
	2.3	(5-8)	This is yet another evidence ... (). [...].
	2.1/2.2	(9-14)	The northward tapering structure of ... indicates that .... [...].
	3.1	(15-16)	It may be therefore inferred that .... It is likely that ....
PAK-24	2.1	(1-2)	As in the Chilas area, ... rocks are emplaced ... in Thurly Gah area. Our study leads to the following results [?] ....
	2.2	(3-10)	The ... division of ... () is supported by .... [...].
	2.3	(11)	Similar ... bodies ... are also consdered to be ().
	2.1/2.2	(12)	The pervasiveness of ... suggest that the emplacement ....
	3.1	(13)	It is hoped that ... aspects outlined here will provide a better understanding ....
	3.3	(14)	However, in the absence of detailed ... work, it is difficult to sort precise ....
	3.2	(15-16)	Jan et al., () invoked ... Nelsund () has also suggested ....
	3.1	(17-18)	Nevertheless, an attempt can be made here to outline a model for .... Taking into consideration ... we suggest that ... may represent ....
	3.2	(19-22)	This sort of ... are well documented in recent literature .... [...].
	3.1	(23)	In the light of these considerations, it is suggested that ....

1. ... indicates text omissions.
2. [...] indicates sentence omissions.
3. () indicates citation omissions.
4. > indicates next clause begins a new STEP.

RA NO.	MOVES	Ss	SIGNALS
PAK-25	1.1	(1-2)	The ... data, discussed in the previous sections, is inadequate for .... Still, it is helpful in pointing out ....
	2.1/2.2	(3-7)	Presence of ... and absence of ... suggest a .... [...].
	3.1	(8)	One possibility is that ....
PAK-26	2.1/2.2	(1-12)	The Vs-distributon in the area ... shows clearly .... [...].
	1.1	(13-14)	If rocks are defined by ... then the ... velocities can be estimated .... [...].
	2.1/2.2	(15-18)	With the use of ... () ... the ... velocities are given in Table-1. [...].
	2.4	(19-20)	This confirms Hall's () view that .... [...].
	3.1	(21)	This sugests that if ....
	2.1/2.2	(22-29)	As far as ... it appears from Table-1 that ... are due to .... [...].
	3.1	(30-34)	The correlation between ... suggests a potential for .... [...].
PAK-27	1.1	(1-3)	Mylonites are widely distributed in .... [...].
	2.1	(4)	Such mylonites are common in the Mingora gneisses.
	2.5	(5-6)	The myonites ... however, could not have been formed in this manner. [...].
	3.1	(7-10)	This thrust may have been formed .... [...].
PAK-28	1.1	(1)	The major and ... constraints of the studied lavas are employed in the problem of ....
	1.2	(2-3)	Green () and Frey et al., () suggested that a few ... criteria .... These are .....
	2.1/2.2	(4-5)	Occurrence of spinel ... suggests that .... The absence of ... make ... doubtful ....
	2.3	(6-7)	Mg-value ... are [have been] suggested for ... (). [...].
	2.1/2.2	(8)	Applying this criterion ... it is clear that ....
	2.3	(9-11)	The concentrations of ... are well below the reported range .... (). [...]. The Co abundances in Table 4 lie within the range.
	2.5	(12)	However, it is not appropriate to assume on the basis of only Co abuncances that ....
	2.1	(13)	Close correspondence between ... is further displayed graphically ....
	3.1	(14)	Concentration of ... favours their production in an island arc environment.
	3.2	(15)	Prevalence of the ... is already interpreted fully ... ().
	3.1	(16)	The petrochemistry of ... provides a chemical support for such a supposition.
PAK-29	2.1/2.2	(1-4)	On the basis of physical conditions, ... can be divided into .... [...].
	2.3	(5-8)	The Jijal assemblages are typical of ... ().
	2.1/2.2	(9-10)	The ... coronas ... developed under such conditions that .... [...].
	2.3	(11)	Such coronas have been attributed to ... ().
	2.4	(12-13)	Magmatic processes, such as the one porposed by () cannot be applied to .... [...].
	2.1/2.2	(14)	The formation of ampbibole or ... may be a funciton of ....
	2.3	(15-20)	Griffin and Heier () suggested that .... [...].
	2.5	(21)	However, the pressure was not high enough to promote such a reaction ....
	2.3/2.4	(22)	Bard () suggested that ... and our data do not contradict him although ....
	3.1	(23-25)	The ... coronas producing ... are clearly the result of .... [...].
PAK-30	2.1/2.2	(1-7)	The ... variation diagrams for ... exhibit a transition .... [...].
	3.1	(8-9)	The geochemical ... suggest that they may represent .... probably was produced ....
	3.2	(10-11)	Age evidence of ... is in accordance with .... [...].
	3.1	(12)	They might have been derived from ... >
	3.3	(12)	however, not enough research has been carried out in this regard.

1. ... indicates text omissions.
2. [...] indicates sentence omissions.
3. () indicates citation omissions.
4. > indicates next clause begins a new STEP.

APPENDIX D-1

List of Theme Types in NATIVE RA discussions (Total clauses = 1044)

UNMARKED THEME (669)

MARKED THEME: Topical (78)

After x-ray irradiation, line features ...
After x-ray irradiation, the line features ...
After x-ray irradiation, the natural calcite ...
At 673K, mixtures of marcasite and
At all temperatures and ..., abhurite is ...
At higher concentrations of ...
At higher temperatures, samples transform ...
At low concentrations, Mn ions exist as ...
At lower temperatures, samples do not transform ...
At pressures less than 15 kbar ...
At these locations, a lens of fluid will form ...
By combining and
During electron irradiation, these anomalous ...
During flextural-slip folding ...
During rapid upwelling, quartz nucleation ...
During the course of DLS analysis ...
Except for Na2O and CaO, the GDCs listed in ...
Excluding garnets, the GDC for CaO varies ...
For a given mineral, values for OH and POH ...
For an H1 hydrogen atom ...
For cummingtonite, the calculated frequency ...
For granite or cummingtonite, the best values ...
For ligand compositions with higher Fe/Mg ratios ...
For purposes of comparison of ...
For several elements ... the measured ...
For simple amphiboles, DLS-adjusted ...
For the AlF3(OH)2 species ..
For the entire range of reasonable pressures ...
For the feldspar data-set of ...
For the majority of elements, the detection ...
For the one ligand composition ...
For tremolite, the agreement ...
For tremolite, the best values are ...
For very low frequencies of ...
From grossular, the GDC for ...
From past experiences ...
From pyroxene, the GDc is ...
From shannonite, larnite and ...
From synthetic Na2Si2O6 ...
From the microtextures observed ...
From the standpoint of etch tunnel formation ...
In a crystal-bearing magma, there is ...
In a few cases, major interference cannot be ...
In cummingtonite, the DLS-adjusted ...
In Fig 1c, amphibole appears to ...
In grunerite, Mg substituting for Fe has ...
In layer silicates, Ca lies ...
In low-symmetry topaz ...
In many of the gahnite-bearing ...
In melilites and epidotes, Fe2+ is ...
In nature, and at neutral pH, both phases ...
In our field example, the angles are ...
In pyroxenes and amphiboles, Ca has ...
In some olivine gabbros, the original ...
In some situations ... an interference ...
In such situations, the background ...
In the Besner thucholite, the ellipsoidal ...
In the case of the Mt Roe #1 paleosol, ...
In the case of the RE-rich thucholite ...
In the case of the Wildhorn Nappe ...
In the following section, we present ...
In the olivine gabbros, amphibole and ...
In the Pinnacles Mine sequence ...
In the troctolites, only the orthopyroxene ...
In their studies, the values obtained ...
In these profiles, the Rb-Sr systematics ...
In these rocks, both garnet coronas and ...
In this equation, ...
In this particular field example ...
Like groups I and II, the simplest ordering is .
Of more significance in explaining ...
Of the two authigenic phases, the low-(Ce/La) ..
To date, a full appreciation of ...
Under natural saline conditions, for example in
Until recently, this has not been the case ...
With such high energies, group-II ...
With their relatively low energies ...
Within the internally zoned Aclare pegmatite ...

MULTIPLE: Textual-Structural (76)

Although beyond the scope of the present study ...
Although calculations ...
Although Christian (1975) ...
Although isometric deformation ...
Although it is relatively easy to ...
Although not completely satisfactory ...
Although only a few structure maps have ...
Although pulse-height selection ...
Although the dimensions of the tubes ...
Assuming that no ...
Because GDCs for a compound are additive ...
Because potassium is the only major element ...
Because the procedures are routine, once the ...
Because the results of the present study ...
Because the upper range of magmatic ...
Even if a suitable geobarometer existed ...
Even when friction has ....
Given that initiation ...
Given that the glasses are ...
Having established that ...
Having established that our calculations ...
If a convincing case is to be made ...
If entropies, for example ...
If growth of etch tunnels ...
If Hacker and Christie (1991) are correct ...
If marcasite is slightly S-deficient ...
If not ... then incorrect ...
If resorption scales linm early with ...
If that observation were to be true ...
If the blue emission is caused by ...
If the concept of strike-slip movement ...
If the electron-overlap term c ...
If the faults were less symmetric ...
If the fluid was shifted ...
If the interference is severe ...
If the model of Sides (1980) ...
If this interference is minor ...
If this is correct, then ...
Although the isometric folding model is ...
Although the techniques ...
As the chloride ion concentration increases ...
As the concentration of OH- increases ...
As the derivation from Anderson's equation ...
As the fluid lens is driven away ...
As the orebody and host rocks appear to be ...
As the spread in orientations increases ...
As these folds amplify ...
If we assume, on the basis of ...
If we had not been using ...
If wi is replaced by ...
Since replacement of one OH by ...
Since the Al-O distanc in ...
Since the ClKÂ peak ...
Since the variation in fluid composition ...
That longer tubes
To achieve this,
To explain these characteristics ...
To understand the process ..., we compare ...
Until more data becomes available for ...
Using Roman numerals in ...
When applied to ...
When crystal symmetry restricts ...
When data for μ-mole H2O/CO2 ...
When the same sample was cooled ...
Whereas Na/K values increase with ...
Whereas the K-feldspar probably ...
Whereas the orientation of ...
While it is not possible ...
While there are ...
and if so
but it seems
But solubility is ...
but, it is unlikely
or it may be that ...
Whatever the source of the ammonium ...
Where electron overlap is significant ...

MULTIPLE: Textual-Discourse (156)

According to Cerny and Hawthorn (1992) ...
According to Self et al., (1988)...
Additionally, corona textures are ...
Again, these figures should be used ...
Also, a homogeneous flattening strain ...
Also, bent twin planes and ...
Alternatively, degassing or cooling of magma ...
Alternatively, the assemblages may represent ...
As a consequence, the main control ...
As a result of this process, a coarse sieve ...
As a result, the calculations vary only ...
As Gapais et al., (1991) point out ...
As in the case of fluorite samples ...
As indicated previously, an increase ...
As noted above, the spatial relationship of ...
As pointed out by Heinrich (1981) ...
As pointed out by Heinrich (1981) ...
As shown in Table 8, our calculated ...
First, knowledge of ...
First, the sliding resistence ...
For example, are impurities ...
For example, if the contribution ...
For instance, quartz shows ...
For this argument to have any ...
Furthermore, Harrison (1988) ...
Furthermore, the suggestion by ...
Furthermore, the trend surfaces that ...
Hence, it is incorrect ...
Here, we rely on ...
However,
However, a few garnets ...
However, as shown above, the effect of ...
However, ascent rates are ...
However, evidence such as ... indicates
However, Fitton (1972) pointed out that ...
However, for ossicles ...

As stated earlier, the NaCl2 BN assemblies ...
As such, this suggests a predominantly ...
Chemically, BD83 is ...
Despite a compositional overlap ...
Despite an association with atacamite ...
Despite the discrepancies, the ...
Despite the reduced intensity ...
Consequently, the line features ...
Consequently, the Zn seems to ...
Even with corrections for ...
Finally, previous experiments ...
First,
However, the infleunce of ...
However, the meta-dolomite at Renstrom ...
However, the plagioclase ...
However, the results agree ...
However, the textures ...
However, the total range ...
However, there are others at ...
However, we believe that ...
However, we will consider ...
In a contribution
In a strict sense
In addition to increased garnet stability ...
In addition, anticrack faulting has been ...
In addition, Figure 2 shows ...
In addition, relict deformed spheroidal ...
In addition, the roles played by ...
In addition, the stress distril Bution ...
In agreement with the bulk analytical work ...
In all three cases, the spectra from ...
In another case, the results ...
In both cases, the sequence is ...
In both instances, evidence for rattling ...
In conclusion, it can be said that ...
In contrast to albite ..., the samples ...
In contrast to black smoker chimneys ...
In contrast to the case of ...
In contrast to the sharp ...
In contrast, any ammonium ...
In contrast, Tingle et al., (1991) ...
In contrast, Wilkinson notes that ...
In fact, both processes ...
In favorable circumstances, there are ...
In one case, for example, duplicate analyses ...
In regard to the third assumption ...
In this respect, it is interesting to note ...
*It follows that ...
*It is noted above
Later, the tubes heal into linear arrays ...
Likewise, the ascent rate is ...
Moreover, as the greatest majority of ...
Moreover, minerals of the ...
Moreover, the continuum dips ...
Nevertheless, the calculations ...
On the basis of
On the basis of our results ...
On the basis of the amount of ammonium ...
On the basis of this comparison ...
On the other hand,
However, from textural evidence ...
However, from values of m
However, Green at al., (1992) ...
However, if the equilibrium composition ...
However, in the case of ...
However, it is important to note that ...
However, much of the variation ...
However, phosphate minerals have ...
However, scaling of ...
However, the brockite ...
However, the direct measurement of ...
However, the higher concentration of ...
On the other hand, direct evidence for ...
On the other hand, the reversely zoned ...
Overall, the fault system ..
Regardless of what factors ...
Second,
Second, an order of magnitude ...
Second, the orientations of the ...
Similarly, deformed sulphides are ...
Similarly, Mg-bearing octahedra ...
Similarly, Murata et al., (1953) ...
Similarly, textures ...
Similarly, Th, U and Ca substitute ...
Subsequently, increasing H2O ...
That is ...
Therefore, as long as ...
Therefore, in light of our experiments ...
Therefore, it appears ...
Therefore, pressure solution and ...
Therefore, resorption must also occur ...
Therefore, the retrograde metamorphism ...
Therefore, we employed ...
Therefore, we interpret ...
Therefore, we must conclude ...
Third,
Third, the flat-stage technique ...
Third, the level of acoustic emissions ...
Thus the calculated position ...
Thus the most important feature of ...
Thus,
Thus,
Thus, any combination of ...
Thus, friction is ...
Thus, in a deforming sedimentary succession ...
Thus, it is not inconceivable that ...
Thus, movement of the thrust ...
Thus, reports of SnCl2 on ...
Thus, the distinction between ...
Thus, the physical processes ...
Thus, the polarizability is ...
Thus, those chemical and ...
To some extent, the large number of ...
Unlike the adiabatic gradient of a pure liquid,
Unlike the unweathered Mt Roe #1 basalt ...
With exception,
With reference to ..., pyrite in the ...
With regard to hydrogen bonding ...
With regard to the local structural ...
With the exception of the two samples ...

MULTIPLE: Interpersonal (52)

As anticipated ...
As expected, they show ...
By all indications, the differences in ...
By chance, it fits
By contrast, the sample of yellow fluorite ...
By further extension, and by analogy ...
Clearly, it would be desirable ...
Clearly, the coronas reflect ...
Evidently, the group-III orderings are ...
I believe that it is
In general, the agreement seems ...
In general, the garnets are ...
In general, the nucleation of ...
In particular, a certain critical ...
Immediately after an increment of ...
Indeed, ...
Indeed, the overall U-content is ...
*It is apparent that ...
*It is evident that none of the ...
*It is likely that the ...
*It is perhaps noteworthy that ...
*It is possible, therefore, that ...
*It is unlikely
*It is unlikely that ...
*It is unlikely that the S-i bonds ...
*It may be expected that ...
*It may well be
*It seems quite reasonable that ...
*It should also be noted that ...
*It should be noted that ...
*It should be noted, however, that ...
*it will be interesting to see ...
*It would be interesting
Most problematic of all,
Note also that the Cu-Cl apical distances ...
Numerically, the two usages ...
Perhaps the nucleation of ...
Possibly, 4-coordinated Li and Be introduce ...
Presumably, this situation would ...
Realistically, it would be necessary ...
There are many possible sources of ...
There is also some question ...
There is some evidence from ...
There is, of course, incontrovertibe ...
To suggest that ... is to enter
Unfortunately, it is nearly impossible ...
Unfortunately, such ambiguity ...
Virtually, all of the feldspar crystals ...
When do etch tunnels stop growing ...
Why is etch tunnel formation sensitive to ...
Why the ordering did not proceed ....
*It is an important point that ...

POSTPONED (13)

It is for this reason that ...
It is only because these differences ...
It is, however, kinetic factors ...
It has been argued ...
It is difficult to interpret ...
It is not difficult to envisage ...
It is suggested that ...
It is suggested that
It is suggested that ...
It is suggested that ...
It is then a simple matter to ...
It is, therefore, extremely difficult ...
There has been a tendency to ...

***Note:** Although these are basically *postponed themes,* they are included in the textual and the interpersonal categories as they contain either a textual or a modal meaning.

APPENDIX D-2

List of Theme Types in PAKISTANI RA discussions (Total clauses = 760)

UNMARKED (509)

MARKED: Topical (59)

Among the three ...
At 20 wt% Al2O ...
At Budsari ...
At temperatures ...
Based on petrographic observations ...
Based on their lithologic column ...
By the late Maestrichtian ...
By the Maestrichtian ...
Due to the complete absence of ...
During flood conditions ...
During the overgrowth ...
During uplift ...
Elsewhere, for instance in the part of ...
Except the garnet ...
For details of ...
For that finding ...
Further north, it rises and ...
In a number of places ...
In chlorite-epidote
In Figure 1 ...
In Koga, the fenitization of ...
In most rocks, the reaction reached ...
In sequences of the Ghazij Formation ...
In such a case, alkaline (high pH) and ...
In such a case, the origin of the ...
In the Indian molasse sediments ...
In the Jijal-Patan complex ...
In the lake deposits of
In the latter, the deformation is ...
In the Malakand granite
In the non-marine sedimentary basine ...
In the plutonic blocks from ...
In the presence of water ...
In the studied gabbros of ...
In the studied perodotite ...
In the ultramafic cumulates ...
In this figure, all the trends ...
In well-drained soils ...
Locally, the formation
Mostly, the pellets are ...
Normally, in the oceanic crust,
Of all the heavy minerals found in the ...
One of the confusing aspects ...
One possibility
On many of the discrimination diagrams ...
On the basis of chemical data,
On the basis of grain size ...,
On the basis of petrographic
On the basis of physical conditions,
Over pyroxene-granulites ..., Vs appears high ...
Presently, the basic rocks ...
Recently, Simpson (1983, 1985) has described ...
South of Kach, there is no sign ...
Together with the A-type granites ...
Until such time, it would be
Westward, the Panjal fault is ...
With crystallization of orthopyroxene ...
With the present limited data available ...
With the use of estimated ...,

MULTIPLE: Textual-Structural (35)

Although the heavy mineral assemblage ...
Although these spinels plot in ...
Applying this criterion ...
As alkaline rocks the world over are ...
As the alkalic nature of these pyroxenes ...
Because both, being of high velocity, can ...
Considering crystallization ...
Considering the crystallization ....
Considering the granite crystallization ...
Despite the fact that rocks ...
Since the Baghdarra fault ...
Subject to uncertianties ...
Taking into consideration ...
Though some high pressure crystal ...
when pyroxene
When pyroxene
Whereas in both Hettash and Rhum intrusions ...
Whereas the external zone ...
Whereas the recognition of faults in ...
and

If replacement of pyroxene ...
If retrogressed rocks
If rock are defined by ...
If the former,
If this distribution is compared with ...
Ignoring the crystallization of ...
Leaving apart the basement gneisses ...
Since Chlorides
And if the latter is true ...
and the uppermost facies PF4
And thirdly, they do not ...
but it is now possible to assign ...
But some may also have developed ...
But the observation is opposite.
but Vs is similar.

MULTIPLE: Textual-Discourse (112)

According to Allen (1978) ...
According to Dick and Bullen (1984)...
According to Jan (1977a) ...
According to the delta model ...
Additionally, there is a close ...
Also, a number of new minerals appear ...
Also, as mentioned earlier ...
Also, by the early Devonian ...
Also, in basic rocks, brown biotite ...
Also, the Rb-Ce segment of the pattern ...
Apart from this broad picture ...
As concluded by Phillips (1980) ...
As far as retrogressed ... are concerned ...
As far as the contribution from the Kohistan ....
As far as the general concentration ...
As for chemical sedimentation of ...
As for montmorillonite, it occurs in ...
As in the Chilas area, ultramafic and ...
As mentioned earlier, the occurrence of ...
As stated earlier, the trace element chemistry ...
As stated in the previous section ...
As suggested earlier, the biotite-amphibolite ...
Besides, such a high Ca-rich plagioclase ...
Despite a constrasting composition ...
firstly, the chemistry of ...
Firstly, their attitude is ...
For example,
For example, Becke (1988) suggested that ...
For example, the cataclasized porphyritic ...
For instance, amphibole is amongst ...
For instance, certain phases of ...
For instance, Kempe (1973) reported ...
From the above discussion, it is clear that ...
Further, he adds that ...
Hence, it is inferred that these illites ...
Here, not only most of the ...
however,
However,
However, a complete lack of ...
However, albite, orthoclase ...
However, in the absence of ...
However, it is not appropriate to assume ...
In addition, the content of ...
In case of primary magmas ...
In comparion, the trace element pattern ...
In conclusion, it is likely ...
In contrast to the fenitic pyroxene ...
In essence, the sediments of the ...
In fact, the intensities of ...
In fact, the superimposition of ...
Initially, during Campanian, the volcanic ...
In particular,
In reality, the sequence is ...
In spite of an overall ...
In the case of the AGC, the porphyroclasts ...
In the light of these considerations ...
In these respects, the Duke Island and ...
In this case, fenitic pyroxene ...
In this case, the larger clasts are ...
In this case, very little ...
In this context, Na-metasomatism can be ...
In view of these ..., it is suggested that ...
In view of this estimation ...
In view of this, the clinopyroxenes ...
Instead, clinopyroxene and orthopyroxene ...
Moreover, biotite has ...
Nevertheless,
Nevertheless, an attempt can be made ...
Next, in-channel flow can ...
On the contrary, even the most ...
On the contrary, the area south of ...
On the other hand, Moluski and Matte (1984) ...
On the other hand, sandstone of ...
On the other hand, the silica-rich granite ...
Rather, more than to any other affinity ...
Secondly, radiometric age data are ...
Secondly, the basal sequence of ...
Similarly, the dino- and orthopyroxene ...
Similarly, the Sirikot fault is ...
Still, it is helpful in ...
Taken together, the evidence suggests ...
Then, there is the basic magmatism ...
Therefore, any igneous hornblende ...
Therefore, as mentioned earlier, the growth of ...

However, large bodies of ...
However, lithofacies ...
However, little was known ...
However, Na-pyroxene ...
However, similar age ...
However, the calcalkaline affinities ...
However, the limestone beds ...
However, the major, trace and REE geochemistry ...
However, the normative composition ...
However, the pressure was ...
In addition,
In addition to some evidence ...
In addition, Kemp (1973) has determined ...
In addition, the calc-alkaline character of ...
Therefore, considering ...
Therefore, on the basis of ...
Therefore, P-T conditions ...
Therefore, the lower K/Rb ratio ...
Therefore, their crystallization ...
Therefore, these gneisses ...
Thus, it is inferred that ...
Thus,
Thus, and as already suggested ...
Thus, during the Silurian, a widespread rifting ...
Thus, in these deposits, the presence of ...
Thus, it is suggested that ...
Thus, the 2M illites ...
Unlike the case of basic magmatism ...

MULTIPLE: Interpersonal (25

Evidently, the strata lying between ...
Indeed, the heavy-mineral suite of ...
Interestingly, whereas the strata older than ...
*It can be noticed from Table-1 that Vp for ...
*It cannot, however, be ascertained that ...
*It is hoped that the field and ...
*It is likely that the Zhob ophiolites ...
*It is not very clear whether ...
*It is obvious from ... that ...
*It is obvious that Vp spiking ...
*It has to be noted that ...
*It has to be noted that a similar ..
*It is interesting to note that ...
*It is possible that ultramafic rocks ...
*It is, however, likely
*It may be concluded that ...
*It may be said that ...
*It may be therefore inferred that ...
Obviously, for a precise determination of ...
There is a possibility that ...
There is a possibility that ...
Unfortunately, all the chemical data ...
We, however, do not believe
*It has to be noted that a suite of dykes ...
*It is appealing, however, to consider ...

POSTPONED (20

It is the petrography which would ...
It has been argued ...
It is further proposed that the term ...
It is proposed that the lowermost shale ...
It is proposed that the name Bibai Formation ...
It is suggested that ...
It is therefore inferred that ...
This [sic] is, however, not understood that [sic] why ...
There is, however, a major difference ...
There is, however, a stronger indication ...
It is, therefore, inferred that ...
It is, therefore, suggested that ...
There are distinct differences ...
There are, however
There are igneous
There are strong reasons to think that ...
There are undeformed pellets for ...
There have been suggestions ...
There is a strong indication that ...
There is decrease of Al2O3 ...

***Note:** Although these are basically *postponed themes,* they are included in the interpersonal category as they contain modal meanings.

APPENDIX D-3

List of Rhetrical Prosodies in NATIVE RA discussions (Total =1011)

MOOD (18)

(note from Table 1)
(see above)
(see above)
(see also Green and Ringwood, 1968)
(see data in Kolthoff et al., 1969)
(see Fig 12 of Burnley et al., 1991)
(see for example, Okumura 1984)
(see Schidlowski, 1975 ...)
(see Table 3)
Note also that
note in Fig 1 that
how do they ... ?
how this figure was derived
what are they ... ?
when do etch tunnels ... ?
Why is etch tunnel formation ... ?
Why the ordering did not
are impurities segregated ... ?

MODALITY (200)

a probable molecular model
almost exactly
Another possibility
apparent (it became apparent that)
apparent at all
apparent that (it is already apparent that)
apparently rise
appear (do not appear)
appear characteristic
appear complex
appear to be
appear to be
appear to be (does not)
appear to be authigenic
appear to be related
appear to have been reset
appear to have been variably reset
appear to heal
appear to postdate
appears not to be so clear
appears to be
appears to be
appears to be
appears to be
appears to be
appears to be
appears to be (it appears to be)
appears to be true
appears to dominate
appears to have
appears to have been
appears to have been related
appears to have been reset
approximately
approximately ... apart
approximately 6d at 673K
arguably not significant
Clearly
clearly authigenic
completely certain
completely satisfactory (not)
considerably less
considerably smaller
consistently close
correctly reproduce
evident (It is evident that)
Evidently
fairly closely
fairly continuous
fairly representative
fairly representative
fairly representative
fairly small angles
fundamentally different
general lack of
generally
generally been attributed
generally correlated
generally exhibit
generally held to be
generally inclreae
generally shorter
generally supersaturated
generally upheld
generaly >60 mol.%
implicitly controlled
implies a more ionic bond
implies negligible diffusion
implying that
In general
In general
in general
In general
in general
in particular
in particular
In particular
is apparent

clearly defined
clearly demosntrated
clearly more accurate
Clearly,
it is not clear
it is not likely that
it is possible
it is still unclear
it is unlikely
It is unlikely that
it seems unlikely
it still appears
likely
likely (It is likely that)
likely played
likely source of this Sr.
likely to be
likely to come
more nearly approach
more nearly approach
more or less evenly distributed
more plausible
most closely to
most important factor
most important feature
most likely hydrated phosphate
most likely source
most likely to break
nearly adiabatically
nearly always retrograded
nearly as compositionally dependent.
nearly impossible
nearly the same
normally involved
not necessarily true
only modestly dependent
only partly reset
only slightly higher
partly reset
Perhaps
perhaps
perhaps (It is perhaps noteworthy)
perhaps a sixth
perhaps combined
possibility (one possibility)
possibility of trace-element
possible (it is possible to carry out)
possible (It is possible)
possible ascent rates
possible dangers
possible explanation
possible sources of ammonium
Possibly 4-coordinated
possibly a result
possibly because of uncertainty
possibly chloride
possibly from error
possibly in the presence of
possibly inherited
possibly on uplift
Presumably
it appears that
It is apparent
it is apparent
it is difficult
primarily
probable error
probably
probably accompanied
probably be
probably common in
probably crystallized
probably do not contain
probably due to
probably F as well
probably formed
probably has both
probably have produced
probably is saturated
probably not
probably not very important
probably occurred
probably of similar strength
probably owing to
probably present
probably reflects
probably represent
probably reset
probably spurious
probably substitute
probably the mild
probably the resultof
probably the thermodynamically
probably those
probably too deshielded
proportionately higher
quite radiogenic
rarely if ever
said to be applicable
seems (It seems quite reasonable)
seems reasonable
seems to be best
seems to have been
seems to represent
slightly
slightly greater than
The possible sources
thought to be important
thought to have formed
typical for samples
typically 45-50°
typically found
typically in the order of
typiocally initiated
unlikely (It is unlikely that)
unlikely (It is unlikely)
unlikely origin
usually exhibit normal
usually of quartz
vary slightly
Virtually all of the feldspar
virtually identical

MODAL VERBS (269)

can adjust its configuration
can alter
can amount to
can arise
can be applied easily
can be avoided
can be balanced
can be broadly accounted for
can be combined
can be confidently obtained
can be considered
can be distinguished
can be encountered
can be expected
can be expected
can be expressed
can be expressed as
can be located
can be made using
can be meaningful
can be readily carried out
can be recast
can be reiterated
can be said (it can be said)
can be seen
can be seen (in Table 5)
can be seen (it can ...)
can be seen from Table 1.
can be taken
can be used
can be used
can be used
can be within
can calibrate
can contain potassium
can easily be avoided
can easily substitute
can exist
can highlight
can influence
can only be inferred
can persist (It can ...)
can resorb
can result
can result in
can rise and fall
can then be estimated
can therefore have
can use
can usually avoid the problem.
cannot be avoided
cannot be determined
cannot be determined
cannot be known
cannot capture
cannot completely
cannot define
cannot explain
cannot form by

could be
could be argued (it could ...)
could be determined
could be enhanced
could be explained
could be interpreted
could be subsequently rimmed
could explain
could form
could have become
could have been formed
could have been incorporated
could have been introduced
could have contributed
could have occurred.
could not derive
could not have formed
could speed the transformation
could the be calculated
could then grow along
could thus aproduce
could yield
may (may vary slightly)
may account for
may all be systematically
may also (this may also ...)
may also arrest resorption
may also be expected
may also explain
may also explain
may also form
may also have been
may be a consequence
may be a primary
may be accommodated
may be attributable
may be attributed
may be attributed
may be enhanced by
may be enhanced where
may be expected
may be expected (It may be expected)
may be initiated
may be interpreted
may be localised
may be more frequent
may be more hydrated
may be of relevance
may be present
may be quite similar
may be related
may be related to
may be required
may be that (it may be that)
may be used
may be varied
may be very rapid
may be weaker
may be zero

could account
could account for
may have been
may have been
may have been
may have been
may have been caused
may have been deposited
may have been present
may have been produced
may have been stronger
may have c-axes
may have driven
may have great significance (This may have ...)
may have increased
may have influenced
may have occurred
may have resulted
may help to generate
may indicate
may ne antecedent
may not be obvious to all
may not be significant
may occur
may occur
may operate
may partially reflect
may reflect
may reflect
may represent
may represent a reaction
may result
may significantly
may still be confidently identified
may well be that (It may ...)
might also be caused
might at first be thought.
might be attrributed
might be caused
might be inherited
might be interpreted
might be modeled
might be possible
might differ
might give rise
might have
might not be effecive
must (not only must interference ... be considered)
must also have been
must also occur
must be
must be argued
must be assumed
must be at least
must be attempted
must be crystallised
must be deleted
must be less than
must be used
must have been
must have been dissolved
may develop
may even be possible
needs to be avoided
should
should (It shoudl be noted)
should (It should also be noted)
should (should vary slightly)
should be cut
should be regarded
should be stabilized
should be used as a guide only
should be used with care
should be used with caution
should fall within
should not conlude
should, however, keep in mind
should, therefore, be comparable
will be a local
will be determined
will be drawn
will be driven
will be interesting (It will be)
will be present
will be similar
will begin to
will coarsen
will counteract
will form along
will give equally good results
will modify
will occur
will occur in a
will occur only when
will promote dissolution
will wither he horizontal
will yield
would
would (it would be desirable)
would (one would expect)
would (probably be)
would affect
would allow
would be
would be a ready source
would be a species
would be accompanied
would be AlF
would be established
would be expected
would be expected
would be gained (little would be gai
would be in
would be interesting (It would be)
would be necessary
would be reasonable
would be required
would be rhabdophane
would be richer in La.
would be S3
would be slightly broader
would be tedious

must have contained
must include
must occur at
need to be questioned
would certainly be difficult
would explain
would gradually decay
would have
would have
would have been
would have been lost
would have behaved
would have released
would involve breaking
would make (This would make ..)
would be to derive
would be unlikely (poses questions t
would be well below
would cause an earlier
would migrate
would not be expected
would not be regarded
would not be solved
would pertain to
would presumably
would result
would slightly shield
would suggest that
would, however, be unusual

COMMENT: Attitude/Evaluation (139)

A characteristic feature
a fact reflected
A key observation
a significant fraction
a special case of maximum likelihood
actually substantially below
An important observation
An important property
An interesting subsidiary
Another important observation
another problem
at least
at least
at least (a significant fraction)
at least an order of
at least consistent
at least under
By chance
By contrast
careful consideration
careful placement of
carefully investigated
Caution is advocated
collectively, if not individually
commonly show
desirable to perform
difficult to apply
directly analogous
do not exactly match
do not need to be
easily anticipated
especially
especially
especially as evidence
especially in simple shear
especially the pyrite
especially with regard to
essential (it is essential that)
essentially Guassian distributed
essentially identical
essentially nonesictent
extensively altered
extensively clouded
In fact
incontrovertible evidence
incorrect in principle and (It is)
Indeed
indeed present
Indeed,
It is an important point
It is difficult to interpret
it is difficult to reconcile
it is important to be able to
it is important to note
it is important to note that
it is interesting to note
it is not compatible
It is not difficult
it is not inconceivable
it is tempting to consider
It is therefore extremely difficult
largely unknown
little increase
little influence on the energy
little influence on the location
mainly of Sr-bearing
mainly with the host
maximum likelihood
more commonly observed
more like being abhurite
most markedly
Most problematic of all
most reasonable interpretation
most reasonable interpretation
mostly biotite
mostly to do
much more closely
necessary (it is necessary)
not significnat
of course
Of more significance
on average
One obvious reason
One of the most striking features
originally similar
particularly no change

extremely sensitive
good only for
highly unusual
important implications
impossible at such pressures
reasonably close
reasonably close
reasonably consistent
relatively easy
relatively insensitive
several advantages
Several previously reported observations
significant difference
significant scatter
significantly
significantly different
significantly different
significantly lower
significantly lower
significantly lower
simple matter (It is then a simple matter)
strong circumstantial evidence
strongly correlated
strongly influenced
strongly porphyritic
strongly suggest that the pyrobitumen
strongly suggests
Realistically
reaonably close
reasonable precision
reasonable variations

strongly suggests
strongly suggests that the thucholit
sufficient quality
the fact that
the fact that
The fact that
The formally correct way to proceed
The importance of careful investigat
The important achievement
The inference is
the likelihood that
too high by as much as
too small to allow
undoubtedly
undoubtedly
undoubtedly represent
Unfortunately
Unfortunately,
very difficult to obtain
very important
very improtant
very improtant

TEXTUAL: Organising (131)

(estimated above for ...)
already noted in
as describe are
as has been observed
As in the case of
As indicated previously
As noted above
as shown above
As shown in Table 8
As stated earlier
considered here
derived above
described above
described above
described above
described above
described above
described here
described here
described here (The methods ...)
described in this paper
descriptions above
discussed above
discussed above
discussed above
discussed above
disucssed earlier
Fig 1 (cuts of Fig 1)
Fig shows
Fig 2 shows
Figure 2 illustrates
firstly
For a given mineral
For an H1 hydrogen atom
For cummingtonite
For granite or cummungtonite
For ligand compositions
For purposes of comparison
For several elements
For simple amphiboles,
For the entire range of
For the feldspar dataset
For the majority of elements
For the one ligand composition
For this argument
For tremolite
For tremolite
For very low fractions
from the above data
given in Table 2.
Having established that
Having established that
Here
illustrated in Fig 6(e).
in a contribution to this debate
In a few cases
in Fig 1b
In Fig 1c
in Figure 1
in Figure 1
in Figure 1 are
in Figure 7

Figure 2 is a map of
Figure 2 shows
Figure 6 is intended
Finally,
First
First,
First,
In this equation
in this paper
in this study
in this study
in this study
It is noted above
just discussed
listed in Table 1
listed in the average column of Table 1
obtained above
presented here
presented here
presented in this paper
referred to in the introduction
results in Tables 2 and 3
Second
Second,
Second,
shown in Fig 1.
shown in Figure 1
shown in Table 4
studied here
Table 2
Table 2 gives
Table 2 shows
Table 3 lists
Table 4 lists
Table 5 compares
in Figures 1 to 4.
In one case,
In regard to the third assumption
in Table 5
in Table 5.
In the following section
in the present paper
Table 5 demosntrates
Tables 3, 4 and 5 report
textures described
the above calculation
the above considerations
the assumption made earlier
the present paper
the present study
the present study
the present study
the present study
The results reported in Table 2
The summation for Table 5 uses
The table also gives
These data
These studies
Third
Third
Third,
This also implies
this paper
this study
This work
With reference to
With regard to
with regard to
With regard to hydrogen bonding

TEXTUAL: Interpretive (179)

a conclusion backed up by
A detailed discussion
A final point of comparison
A possible explanation
According to ..
Additionally
Also
Also
Alternatively,
Alternatively,
As a consequence
As a result
As a result of
As anticipated
As expected
as expected
As pointed out by
As pointed out by
As such,
As the derivation ... shows
Assuming that
for example
for example
for example
for example
for example
for example
For example
For instance
From the standpoint of
Given that
Given that
If a convincing case is to be made
If that observtions were to be true
If the concept of
If this is correct
In addition to
In addition
In addition
In addition
In addition
In addition to

At all tempratures ... studied
By all indications,
By further extension and by analogy
calculations show
compositionally intermediate
Consequently
Consequently
defined by equation (1)
for example
For example
in contrast to
In contrast to
In contrast to
in contrast to
in contrast to the pure shear
in most cases
In some situations
In such situations
In the case of
In the case of
in the case of
In the case of
in the light of
In their studies
In this respect
Increasing salinity
Increasing the
is interpreted
It follows that
It has been argued
It is suggested
It is suggested
It is suggested that
It is suggested that
Likewise
Moving from pulse 1 to pulse 2
Nevertheless
on that basis
on the basis of
On the basis of
On the basis of
on the basis of
on the basis of
On the basis of
On the basis of the amount
On the other hand
on the other hand
on the other hand
On the other hand
on the other hand
On the other hand,
on these textural grounds
Overall,
previous study
qualitatively correct
in addition to enthalpies
In all these cases
In another case,
In both cases
In both instances
in conlclusion
In contrast
In contrast
In contrast
In contrast
Similarly,
simple working hypothesis
Subsequently
Such an interpretation
such as (evidence such as)
taken into account
taken to be the original
taking note of
that conclusion
the assumption that
the conclusion that
the hypothesis that
the implication is
the latter interpretation
the notion that
the observation that
the observation that
The observation that
The observation that
the present calculations
The present microprobe results
The principle is
The result
The results indicate
The results of this approach
then
theoretically possible
theoretically unsound technique
There is also some question
There is some evidence
These characteristics
These results
These results
These results add
this calculation
This choice
This conslusion is
this discrepancy between
this final equilibration temperature
This in turn tend to support
This investigation
This is an unexpected result
This is straightforward
This latter type
this notion

Regardless of what factors
requires modification of this view
respectively
respectively
respectively
respectively
respectively
respectively
respectively
Similarly
similarly
Similarly
Similarly
Similarly
This point needs to be emphasized
This practice
this problem
This procedure
This provides support
This result
This sequence
This technique
This theory
To date
to enter a debate
To suggest that
Until more data becomes available

TEXTUAL: Stylistic (13)

Chemically
In a strict sense
in terms of
means that
Numerically
That is
To achieve this
To explain these characteristics
to understand why the spectrum
To understnad
using corresponding values
Using Roman numerals
using the data of Table 2

PERSON USE (64)

I have mapped
I (believe that)
my field example
one of the authors
our calculated
our calculated
Our calculated Na values
our calculated shieldings
our calculations
Our experimental results
our experiments
our experiments
our experiments
our field example
our molecular model
our petrographic examination
Our previous calculations
our range of
our results
our results
our samples show (all our samples)
We assign
We assume
we assume that
we assume (If we assume)
we believe are (what we believe)
we compare
We conclude
We conclude
we consider
we constructed
we expect
we expect
we had not been (If we had not been
we have chosen
we have examined
we have learned that
we have monitored
we interpret
we interpret
we must conclude
we nonetheless feel
we observed
we outline
we present
we rely on
We suggest
We suggest
We summarize
We suppose that
We therefore concur
We therefore suggest
we will consider
we believe
We (We can calibrate)
we (we can use)
we (we cannot completely)
we (we would have)
we ... refer to
one would expect
The reader
The reader

APPENDIX D-4

List of Rhetrical Prosodies in PAKISTANI RA discussions (Total =465)

MOOD (8)

(... see Mongkol and Ashworth, 1983).
(see Abbot, 1967).
(see Ahmad, 1986, p. 18)
(see Basaltic volcanism study project, 1981 ...)
(see Hamidullah, 1983; ...)
(see Miyashiro, 1973).
(see Paterson and Windley, 1985 ...)
(see Pearce et al., 1984 for ...)

MODALITY (153)

always located
apparently developed
apparently reverse
appear to be distal
appear to have taken place
appears fairly similar
arbitrarily selected
clearly multistoried
clearly reflected
clearly reflects
clearly signify
clearly the lateral
clearly the result of
Close correspondence
close textural relationship
closely comparable
coincides closely
commonly associated
commonly enclosed
commonly with nodular
considerable analogy
considerably lower
essentially a product of
essentially characterize
essentially composed of
essentially comprise
essentially strain-related
evidently suggests
Evidently,
fairly uniformly distributed
found mainly in the Indus
general negative Nb anomaly
generally
generally associated
generally brittle
generally correspond
generally correspond
generally crystallise
generally diachronous
generally exhibits
generally interbedded
generally referred to
generally restricted
generally scarce
generally shows
in fact invariably used
in general are texturally mature.
in general rounded
In particular
in particular in terms of
In reality,
invariably associated
invariably contain
it appears from Table-1,
it appears that
it becomes clear that
It has to be noted
It has to be noted
It has to be noted that
it is clear that
It is further proposed
it is helpful vaguely defined limits
It is hoped that
it is inferred that
it is likely that
It is likely that
it is not appropriate to assume
It is not very clear
it is now possible to assign
It is obvious from
It is obvious that
It is possible that
It is proposed that
It is proposed that
it is sugested that
It is suggested that
It is, however, not understood
It is, therefore, inferred
It is, therefore, inferred that
It is, therefore, suggested
largely comprised of
mainly a function of
mainly due to
more or less close to
more or less in the range of
more usefully elucidated
most of the older part of
most probably
mostly associate with
mostly foraminifera

generally significant
has probably played
In fact
In fact
One possibility is that ...
partly made
perhaps due to
perhaps with minor current
possibility of their development
possibly of ephemeral nature
possibly over
possibly partial melting
possibly the
predominantly consists of
presumably passed through
probable explanation
probably a high degree
probably alternated
probably at a
probably at higher levels
probably deposited
probably derived
probably developed
probably due to
probably due to
probably due to
probably due to
probably due to the fact
probably entered
probably from the core
probably in Early Triassic.
probably indicates
Mostly the pellets are
Normally,
Obviously,
Occasionally it
probably of the order of
probably operative
probably related
probably represent
probably the result of
probably to tight folding
probably underwent
probably was produced
probaby occurred
rarely larger than
resembles closely
seems to be a differentiate
seems to be appeared [sic]
seems to be much older
seems to be the
seems to have been consumed
Some possibilities are: 1) 2) 3)
The occasional replacement of
The possibility of
There is a possibility
There is a possibility
there is every possibility
tpically found
typically at those margins
typically distributed
usually of detrital origin
virtually unmetamorphosed sediments

MODAL VERBS (107)

can be attributed
can be attributed
can be attributed to
can be classified
can be considered
can be divided
can be divided into
can be estimated
can be explained
can be explained
can be made here
can be monitored
can be noticed
can be obtained
can be of several different origins.
can be related
can be related to
can be related to
can be related to
can be therefore considered
can erode
can produce a velocity jump.
can provide useful clues
cannot also be ruled out
cannot be attrributed
cannot be overruled
cannot be ruled out
could have formed
could not have been formed
could not more coexixt
could not stably coexist
could not transport
could then be
may also be formed
may also be noticed
may also have developed
may also have existed
may also suggest
may be a function of
may be brought about
may be concluded
may be considered
may be considered then
may be derived
may be due to
may be due to (This may be)
may be less voluminous
may be metasedimentary
may be of the same age
may be of the same age
may be preserved
may be representing
may be said
may be similarly obscured

cannot be unequivocally called
cannot, however, be ascertained
could be due to
could be simultaneous
may cut the others
may have a link
may have been formed
may have been transported
may have continued
may have disappeared
may have eroded
may have formed
may have increased
may have initially constituted
may have occurred
may not crystallize
may not have developed
may not shoe regular variation
may partially be associated
may represent
may represent
may represent isolated pulses
may result in
may show extreme elongation
may simply be due to
may undoubtfully have been
may, however, be related
may be some influence
may be sugegsted
may be the plagiogranite
may correspond to
may, therefore, be inferred that
might have been derived
might have been partially
must be older than
must have been varying
must have Mg-values of
should be much higher
should give a gradual increase
will be difficult to produce
would be appropriate to
would be depicted
would be more likely
would be that which
would be the other variable
would favour
would form a major portion
would imply
would in turn
would not be possible
would not be proper
would record a metamorphic
would require a larger quantity

COMMENT: Attitude/Evaluation (46)

a careful examination
A careful examination,
A completely different ... trend
a major difference
a stronger evidence
ample evidence
at least
at least
at least two major phases
charcteristically found
consistenly shows
definite contrast
derived moslty from
Despite the fact
distinct differences
high degree of maturity
highly magnesian
highly questionable
Indeed
interesting to note
interesting to note
Interestingly,
It is apealing ... to consider
it is difficult to sort
little doubt
no evidence of the existence
not enough research
particuarly important
particulalry pronounced
particularly Al2O3
particularly in
particularly those
Presently
Rather, more than
Recently,
strong concordance
strong indication
strongly oppose
strongly reminiscent of
strongly supports
substantially different
The most significant feature
the only alternate origin
There are strong reasons to think
there is a marked change
Unfortunately

TEXTUAL: Organising (52)

above mentioned treatment
already interpreted fully
already mentioned above
As ... has been ruled out above
as already suggested on the basis of
as discussed below
As far as retrogressed ...
As far as the contribution ... is concerned
As far as the the general concentration ...
As for chemical sedimentation of
As for montmorillonite,
as mentioned earlier
as mentioned earlier
As mentioned earlier,
As stated earlier
As stated in the previous section
As suggested earlier
discussed in the previous section
firstly,
Firstly,
From the above discussion
given in Table-1.
Here,
In case of primary magmas
in certain sections
In conclusion,
in Fig 10 to 12
In Figure 1,
In sequences ...
in some related
In such a case,
in Table 4
In the case of the AGC,
In the latter
In the studied peridotite
In this case,
In this case, fenitic pyroxene
In this case, very little
In this figure,
mentioned above
Next
outlined here will provide
outlined in this paper
Secondly,
Secondly,
the following results
The first one occurs
The first phase
the first two methods
the latter two
The second phase is distinctly
thirdly

TEXTUAL: Interpretive (82)

(such as Ambela, Malakand)
According to
According to ...
According to Jan
According to the delta model,
Additionally
Apart from this broad picture
Applying this criterion
As concluded by Phillips,
As in the Chilas area
Based on petrogrphic observations
considering all the genetic ... aspects
Considering crystallisation
Considering the crystallization ...
Considering the granite
Due to the complete absence of
During the overgrowth
for example
For example
For example,
For example,
for instance
For instance
For instance
For instance,
For that finding
Ignoring the crystallization of
In addition,
In addition,
In addition,
In view of this,
interpreted as
Leaving apart
on the assumption that
On the basis of
On the basis of chemical data,
On the basis of grain size
on the basis of its geological positi
On the contrary
On the contrary,
on the other hand
On the other hand
on the other hand
On the other hand
On the other hand
on the other hand
One of the confusing aspects
Similalry,
Similarly
Still,
Subject to uncertainties
such a supposition
such as
such as
such as the ones
suggested for best least refractory
Taken together,
the supposition that
these interpretations
This assumption is

In addition,
In comparison,
In contrast to the
In essence,
In spite of an overall
in the absence of ...
In the light of these considerations
In these respects
In this context,
In view of these
In view of this estimation
This interpretation
This interpretation
This interpretation
this interpretation
This is interpreted as
This is yet another evidence
This observation
three alternative ... mechanisms for
Unlike the case of
unlike the latter
With the present limited data availab

TEXTUAL: Stylistic (2)

i.e.
Taking into consideration

PERSON USE: (12)

one is compelled to relate
Our interpretation
Our present study reveals that
Our study lead to
We are unaware
We assign
we have found
We interpret
We suggest that
we suggest that
We tend to include
We, however, do not believe

Appendix E-1

Native Geology RA Introductions used in the study

NS-01: Tolbachite, Cucl2, the first example Of Cu2+ octahedrally coordinated by Cl-

[1]Tolbachite, CuCl2, occurs in encrustations on basaltic magma flows of the Tolbachin eruption of 1975-1976 and was described as a new mineral by Bergasova and Filatov (1984). [2]It is hygroscopic and hydrates to eriochalcite (CuCl22H2O) on continued contact with air. [3]This feature, along with the general lack of good crystals, presents special problems for structure characterization. [4]The crystal structure of synthetic CuCl2 was determined by Wells (1947), but because of the aforementioned problems, was not refined. [5]The unit-cell dimensions and space group given by Wells (1947) and Bergasova and Filatov (1984) indicate that tolbachite is isostructural with synthetic CuCl2.

[6]We are currently interested in bond-distance variations in Cu22+6 (= unspecified ligand) octahedra in copper oxysalt minerals (i.e., Burns and Hawthorne, unpublished manuscript, 1992; Eby and Hawthorne, unpublished manuscript, 1992). [7]The Cu2+6 octahedra observed in copper oxysalt minerals are almost invariably distorted into a (4 + 2) arrangement because of the Jahn-Teller effect (Jahn and Teller, 1937). [8]In the case of Cu2+6 (= O2, OH, H2O), the octahedral bond-distance distributions observed in minerals are quite well understood and can be quantitatively rationalized by consideration of the Jahn-Teller effect alone (Burns and Hawthorne, unpublished manuscript, 1992). [9]However, a number of Cu minerals contain Cu2+6 octahedra with 33 = O2, OH, H2O, and (1, 2, or 4) Cl- ligands. [10]Because of the mixture of ligands forming these octahedra, the Cu2 ion cannot achieve a strictly holosymmetric environment, and the Jahn-Teller argument is not directly applicable to such polyhedra. [11]However, a near-degenerate electronic state may occur, and a distortion of the octahedron can then lead to a significant net stabilization of the mixed-ligand octahedra. [12]This effect is usually referred to as the pseudo-Jahn-Teller effect (Hathaway, 1984). [13]In Cu2+6 octahedra with mixed ligands, the bond-distance variations are less straightforward to interpret than in the case of O ligands (= O2, OH-, H2O), particularly as we do not have a good value for the ideal equatorial and apical bond distances for a Jahn-Teller-distorted Cu2Cl6 octahedron. [14]Thus, the role of the pseudo-Jahn-Teller effect in controlling the geometry of mixed-ligand Cu26 octahedra is not clear.

[15]We have refined the crystal structure of synthetic tolbachite using powder X-ray diffraction data. [16]Tolbachite is the only mineral that contains Cu2+Cl6 octahedra and gives the bond-distance information needed to evaluate Jahn- Teller relaxation in Cu2+Cl6 and Cu2+6 mixed-ligand octahedra.

NS-02: Kinetics of the marcasite-pyrite transformation: an infrared spectroscopic study

[1]Pyrite and marcasite are naturally occurring phases in the Fe-S system, dimorphs of composition FeS. [2]The pyrite crystal structure is cubic (space group Pa3) with the octahedrally coordinated Fe atoms at the corners and face centers of the cube unit cell. [3]Disulfide pairs lie at the center of the cube and at the midpoints of the cube edges and are oriented such that their axes are parallel to four nonintersecting body diagonals of the cubic lattice. [4]Each S atom is octahedrally coordinated to three Fe atoms and one S atom.

[5]Marcasite has an orthorhombic unit cell (space group Pnnm) and like pyrite, has Fe atoms in octahedral coordination with S, and S atoms tetrahedrally coordinated to three Fe atoms and one S atom. [6]The difference between the marcasite and pyrite structures is found in the linking of the Fe-centered octahedra. [7]In the marcasite structure, these octahedra share two edges in planes normal to (001); in pyrite, the octahedra are linked at corners (Vaughan and Craig, 1978). [8]The pyrite structure can be obtained from that of marcasite by rotation of half of the S2 groups through 90.

[9]Marcasite readily inverts to pyrite when heated under vacuum to temperatures above 673 K (Fleet, 1970; Gronvold and Westrum, 1976; Kjekshus and Rakke, 1975). [10]Murowchick and Barnes (1986), in contrast, reported inversion of very fine-grained synthetic marcasite to pyrite at ambient temperatures, and Rising (1973) found that marcasite readily transformed to pyrite above 433 K under hydrothermal reaction conditions. [11]To determine whether marcasite has a field of stability below 673 K, an investigation of the thermodynamic stability of the two iron disulphides utilizing adiabatic-shield calorimetry was made by Gronvold and Westrum (1976). [12]This study demonstrated that marcasite is metastable with respect to pyrite from 5 to 700K. [13]Above 700 K, marcasite undergoes irreversible exothermic transformation to pyrite.

[14]The difference in G values at 298.15 K for marcasite and pyrite is small; for pyrite, G = -160.060 kJ/mol, whereas for marcasite, G = -156.159 kJ/mol. [15]At 700 K, G for pyrite = -137.074 kJ/mol, for marcasite, it is -133.617 kJ/mol (Chase et al., 1985), based on the data of Gronvold and Westrum (1976). [16]The formation and persistence of marcasite is thus due not to its thermodynamic stability but to kinetic factors.

[17]Whereas pyrite has been synthesized both by high-temperature reaction between elemental Fe and S and by precipitation from aqueous solution, the synthesis of marcasite has been achieved only by reaction of Fe2 and S species in acidic aqueous solutions (Murowchick and Barnes, 1986; Schoonen and Barnes, 1991a, 1991b, 1991c).

[18]Tossell et al., (1981) proposed that the formation of marcasite from acidic solutions is a function o reaction mechanism. [19]A valence counting scheme suggests that the formation of marcasite in preference to the more stable pyrite (with a system of 14 electron diallions) may be a result of ID interaction with the S2 dianion electrons. [20]The effect of the H ion is to withdraw two electrons from the metal 3d-dianion 1g system, giving a distorted geometry to the three Fe atoms coordinated to each S atom of the disulfide group. [21]Loss of H would then expand the M-A-M angle to the value of 97 observed in marcasite.

[22]This model was invoked by Murowchik and Barnes (1986) to interpret experiments that showed a relationship between the pK1 of the polysulfide solution species and the pH of marcasite formation. [23]Murowchick and Barnes argued that, in acidic solutions, the addition of H2S2 to the growing FeS2 surface results in the marcasite structure. [24]The electron valency of H2S2 is effectively the same as that of a 12-electron valent dianion pair. [25]Binding of H2S2 to the crystal surface has an electron withdrawing effect that stabilizes the marcasite structure.

[26]In comparison, when HS is the predominant poly-sulfide species, it is proposed that the proton has no structurally determining effect, and so the more stable pyrite structure is formed.

[27]Schoonen and Barnes (1991c) concluded from experimental work that the rate of direct nucleation of pyrite and marcasite in slightly acidic solutions is insignificant below 573 K. [28]Instead, most pyrite and marcasite in hydrothermal ores form by sulfidation of iron monosulfide precursors. [29]They interpreted the Murowchick and Barnes (1986) relationship of polysulfide pK to formation pH in terms of surface sulfide species on the growing pyrite or marcasite crystal, rather than in terms of solution sulfide species.

[30]In a crystallographic study (Fleet, 1970) of the structural aspects of the marcasite-pyrite transformation, it was found from X-ray measurements that the inversion to pyrite was

partially complete after 12h at 698K and essentially complete at 748K after less than 4h of heating. [31]Attempts by Kjekshus and Rakke (1975) to detect the inversion using differential thermal analysis (DTA) were, however, unsuccessful.

[32]The present study was undertaken to measure the activation energy of this high-temperature transformation and to determine the mechanism by which this transformation takes place.

NS-03: Sieve-textured plagioclase in volcanic rocks produced by rapid decompression

[1]Plagioclase commonly exhibits a variety of disequilibrium textures in volcanic rocks especially in orogenic andesites. [2]These textures often include combinations of complex zoning patterns and resorption features in plagioclase that record changing physical conditions in magmatic systems. [3]Thus the potential exists to learn much about magmatic processes involved in their formation if the textures can be interpreted with the caveat that erroneous inferences may result if a particular texture can arise through more than one process. [4]This study deals with he origin of coarse sieve-textured volcanic plagioclase (Fig. 1) in the light of new experimental observations and petrographic characteristics of resorbed natural plagioclase.

[5]We interpret the texture of the plagioclase in Figure 1 representing the remnants of an interconnecting network of channels developed as the crystal underwent dissolution in response to physical and chemical changes in the magma reservoir or conduit. [6]Initially dissolution allowed diffusive and convective communication of the liquid in the channels with the bulk of the melt. [7]However, in many volcanic rocks sieve-textured plagioclase has euhedral rims that may result from subsequent crystal growth in response to loss of volatiles or cooling prior to eruption. [8]If the rims encapsulate the crystal, this may leave the resorbed plagioclase with entrained liquid inclusions that have no obvious means of communication with the bulk of the magma. [9]Upon extrusion, quenching of the magma leaves he network of channels filled with microcrystalline or glassy melt inclusions.

[10]One interpretation of coarse sieve textures similar to those in Figure 1 is rapid skeletal growth resulting from undercooling (Kuo and Kirkpatrick 1982). [11]However, melt inclusions are commonly elongate parallel to, or abutted against polysynthetic twin planes (Fig. 1) or they cut boundaries between individual crystals in glomerocrysts. [12]Given that glomerocrysts and polysynthetic twin planes form after crystallization (Dungan and Rhodes 1978) the cross-cutting relationships indicate that these textures must form by resorption rather than rapid crystallization.

[13]Two other mechanisms have been proposed to explain the origin of sieve textures in plagioclase from volcanic rocks. [14]They are magma mixing (e.g., Dungan and Rhodes 1978; Tsuchiyama 1985) and magmatic decompression (e.g., Vance 1965; Stormer 1972; Nelson 1989). [15]The possible effects of magma mixing have been experimentally investigated although only under a limited set of conditions (Tsuchiyama 1985). [16]To date, these experiments have not produced textures like those in Figure 1, although future experiments may produce them if they are carried out under an expanded range of pressures, temperatures and compositions. [17]Many studies have shown the widespread occurrence of magma mixing as a petrogenetic process and it is not our intent to dispute its importance. [18]However, our results indicate that coarse sieve textures may result from the rapid ascent of magmas; therefore invoking magma mixing solely on the basis of coarse sieve-textured plagioclase may not be warranted, in the absence of other criteria indicative of magma mixing such as trapped liquid enclaves disequilibrium phenocryst assemblages (e.g., Mg- rich olivine + quartz) or other chemical and isotopic criteria magmatic decompression is a geologically simpler model as it does not require an open system. [19]However, the two processes need not be mutually exclusive. [20]Both mechanisms destabilize relatively sodic plagioclase and all magmas decompress during ascent.

NS-04: The applicability of least squares in the extraction of thermodynamic data from experimentally bracketed mineral equilibria

[1]With the ever-increasing volume of experimental and calorimetric data on minerals, a thermodynamic data set, including data for most end-members of rock-forming minerals, is becoming attainable. [2]An important stage in this development was the recognition that well-determined phase equilibria for reactions among mineral end-members provide excellent constraints on thermodynamic properties. [3]So-called internally consistent data sets involve thermodynamic data calculated from such experimental data. [4]Two methodologies have been used to do this, both involving processing all the experimental data (in some chosen system) at once. [5]One is a mathematical programming (MAP) approach (Berman, 1988): the other is a least-squares (LSQ) approach (Powell and Holland, 1985; Holland and Powell, 1985, 1990; DS1, DS2, and DS4, respectively, DS standing for data sets).

[6]There have been some suggestions that various aspects of the LSQ approach make it inappropriate for data extraction: the aim of this paper is to show why the LSQ approach is not only sound, but also the most appropriate approach.

[7]The essence of the application of LSQ to data extraction as followed in DSI-4 is now outlined. [8]It will be assumed that entropy, volume, and heat-capacity data for end-members of minerals are relatively well known: therefore, the aim of data extraction is to calculate enthalpies of formation of end-members at 1 bar and 298 K (denoted Hf) from the experimentally bracketed equilibria. [9]The extension of the logic to over the case where entropies and other parameters, in addition to enthalpies, are determined is considered in the discussion section below.

[10]We will start by showing how reversal brackets for an experimentally determined reaction may be converted into an enthalpy of reaction representing all the reversal brackets for the reaction. [11]Such enthalpy of reaction data are the input in our LSQ analysis. [12]A typical set of reversal brackets for a reaction are shown in Figure 1a. [13]If only enthalpies are to be found, the slope of the reaction is fixed; the two light dashed lines represent the limits of the range for the reaction if the ends of the bracket are taken to have no uncertainty. [14](For this example, the reaction is taken to be one without curvature). [15]For each bracket in temperature, an equivalent bracket for the enthalpy change of reaction, HR can be calculated, Figure 1b (DSI, p.332). [16]Clearly the two bracket ends (shaded circles), which define the range of position of the reaction, also define the limits of H if the ends of the brackets are taken to have no uncertainty. [17]The resulting HR bracket shown at the bottom of Figure 1b is the cumulative bracket (of DS 1- 4), representing all the T brackets in Figure 1a. [18]Alternatively, a composite HR may be defined in terms of, for example, a weighted average of the midpoints of the H brackets, marked by crosses, giving the solid vertical line in Figure 1b. [19]Regardless of how the information in the individual HR brackets is combined, a representative HR value is generated, as well as some estimate of the uncertainty of this value.

[20]Given a HR value and its uncertainty for each reaction in a set of reactions, the problem is to estimate the enthalpies of formation of the mineral end-members involved in the reactions. [21]If there are the same number of reactions as enthalpies of formation being determined, then enthalpies of formation can be found for any specified position in each HR bracket. [22] However, there are normally more reactions than enthalpies of formation, so the problem becomes one of finding a consistent set of enthalpies of formation that agree with, or fit, the values in some sense. [23]If the probability distribution representing each HR bracket is approximately Gaussian, then the way to find a best fit is by LSQ, in which

the enthalpies of formation are found for which the sum of the squares of the departures of the calculated from the center of the 115 bracket probability distribution, weighted to a measure of the width of the distribution, is minimized.

[24]However, this development raises three questions: [25](1) The first, and the one that has been the main criticism of the LSQ methodology, is that the centers of the brackets are to be fitted, and therefore there will be a tendency to force reactions central to their brackets. [26]This is contrary to the idea that a reaction should be placed anywhere within its bracket, and therefore it has been argued that LSQ is inappropriate. [27](2) It has also been suggested that even though LSQ and MAP give similar results, the uncertainties on the thermodynamic data as calculated by LSQ are meaningless. [28](3) It might also be argued that although an LSQ approach based on every experimentally determined bracket might be appropriate, in parallel to the MAP approach, which uses all brackets, the use of composite data is inappropriate. [29]Discussion of these and related points is the focus of this paper. [30]It will be shown that all of these concerns are unwarranted. [31]We start with a consideration of the probability distribution of H brackets corresponding to individual P-T brackets.

NS-05: Dielectric constants of diaspore and B-, Be-, and P-containing minerals, the polarizabilities of B_2O_3 and P_2O_5,and the oxide additivity rule

[1]Dielectric polarizability, D, is related to the measured dielectric constant, k', by the Clausius-Mosotti equation:

D = 1/b[(Vm)(k'- 1)/(k' + 2)] (1)

where Vm is the molar volume in A, b is assumed to be 42r/3, and ', the real part of the complex dielectric constant, was measured in the range 1 KHz to 10 MHz (Roberts, 1950, 1951). [2]The Clausius-Mosotti equation is strictly valid only for compounds in which the molecule or ion has cubic symmetry (Szigeti, 1949; Bosman and Havinga, 1963, Duffin, 1980, Kip, 1962; Megaw, 1957; Roberts, 1949, 1950, 1951; Dunmur, 1972) but has been shown to be approximately valid for a number of noncubic crystals (Roberts, 1949, 1951; Lasaga and Cygan, 1982; Shannon et al., 1989, 1990).

[3]The concept of additivity of molecular polarizabilities implies that the molecular polarizability of a complex substance can be divided into the molecular polarizabilities of simpler substances according to

D(M2M'X4) = 2D(MX) + D(M'X2). (2)

[4]Previous applications of the additivity rule to minerals were reviewed by Shannon and Subramanian (1989).

[5]The purpose of this paper is to determine the 1-MHz dielectric constants of diaspore and several Be-, B-, and P-containing oxides and minerals, to derive the polarizabilities of B2O, and P2O5, and to evaluate the validity of the oxide additivity rule in these materials.

NS-06: Formation of fluid inclusions and etch tunnels in olivine at high pressure

[1]During the course of experiments to measure the solubility and diffusivity of C in San Carlos olivine by C 7-track autoradiography (Tingle et al., 1988), it was noted that some specimens annealed at high pressure (2-3 GPa) in the presence of CO2, and CO2-H2O contained fluid-filled tubes and inclusions that clearly had not formed by crystal growth or by injection of fluid along fractures and subsequent diffusional crack healing. [2]The tubes we have produced at high pressure are similar in many respects to etch tunnels produced by HF etching of natural and synthetic quartz (Nielsen and Foster, 1960: Hanyu, 1964; Carstens, 1968; Iwasaki, 1977; Folk et al., 1987; Folk, 1989). [3]We have characterized these experimentally induced features to infer the mechanism of their formation and their relevance to geologic processes.

NS-07: Theoretical studies of the speciation of Al- in F-bearing aluminosilicate glasses

[1]Dissolved volatile components in magmas can strongly influence their physical properties and volcanic eruptive behavior. [2]F is one of the most important volatile components, significantly influencing phase relations (Manning, 1981), lowering viscosity (Dingwell, 1989), and increasing diffusion coefficients (Dingwell, 1985). [3]F is also an important additive to industrial silica glasses, where it is primarily used to lower the index of refraction (Duncan et al., 1986). [4]The speciation of F in silicate and aluminosilicate glasses has been inferred from phase relationships (Manning et al., 1980) and has recently been studied by Raman spectroscopy (Mysen and Virgo, 1985), by Al NMR (Kohn et al., 1991), and by F NMR (Schaller et al., 1991a, 1991b). [5] Although some features in the Al and F NMR could be assigned fairly confidently on the basis of comparison with crystalline model compounds, certain weak features could not be so confidently assigned. [6]For example, the Al NMR showed a weak peak deshielded by about 23 ppm from that attributed to '6'AI. [7]The '9F NMR showed one or more weak features about 30 ppm deshielded from the resonance assigned to AIF6 (on the basis of an almost exact match with the F shielding of M3AIF6). [8]The weak Al NMR peak was enhanced by 19F-27AI cross-polarization, indicating that F was bound to the Al, and the resonance was narrow, indicating a small electric field gradient (EFG) at Al.

[9]In both Si and Al NMR, an increased coordination number is associated with increased shielding of the nucleus. [10]For example, fivefold-coordinated Al is more highly shielded than fourfold-coordinated (Alemany and Kirker, 1986; Alemany et al., 1991), just as for [4]Si and [5]Si (Stebbins and McMillan 1989). [11]However, substitution of F for O also deshields the tetrahedrally coordinated nucleus, T, whether Si or Al. [12]Decreasing the polymerization of the aluminosilicate network, i.e., converting bridging O atoms in T-O-T linkages to nonbridging O in T-O-H or T-O-M linkages on the other hand, deshields T (Magi et al., 1984). [13]Finally, the particular value of the T-O-T alo ~~in~~fluences both Si and Al shieldings (Lippmaa et al., 1986). [14]Considerable ambiguity can thus arise in the assignment of an Al NMR resonance to a particular species.

[15]To assist in assigning the 27AI and 19F NMR spectra of F-bearing aluminosilicate glasses, we have calculated using quantum mechanics several properties of a number of aluminum fluorides and hydroxyfluorides that serve as models for possible species in the F-bearing aluminosilicate glasses, in particular AIF4, AIF2 AIF3 Al(OH),, Al(OH)52, AIF3(0H), AIF2(0H)I, AIF2(0H)2, and AIF3(OH)2. [16]For each species, we calculate the minimum-energy geometry using standard self-consistent-field molecular orbital (SCF-MO) methods (Hehre et al., 1986) and medium-sized expansion basis sets. [17]At these optimized geometries, we then calculated the electric field gradient at the Al nucleus and the Al and F NMR shieldings. [18]For some species we have also calculated the vibrational spectrum [although in general Raman spectroscopy does not seem to be a particularly good method for studying aluminum fluoride species, since polarizability changes with bond lengths, and therefore Raman intensities are expected to be considerably smaller than in analogous Si species (Mysen and Virgo, 1985)].

NS-08: Calculated frequencies of O-H stretching for different local orderings of Fe and Mg in simple clinoamphiboles

[1]Abbott (1990) developed and tested a method to determine the short-range potential between the oxygen and hydrogen of hydroxyl groups in amphiboles. [2]The short-range O-H potential was modeled as a simple Born-Huang (1954) exponential, where L and P are constants, and r is the O-H separation. [3]The method involved a search for the L and P values that best satisfy the observed position of the hydrogen atom and the observed frequency of O-H stretching. [4]For tremolite, L and P were determined to be 30500 kJ/mole of H and 0.2560 A, respectively. [5]The values for A and p are consistent with formal ionic charges in the Coulombic contribution to the energy. [6]Whereas the short-range potential seems to transfer reasonably well to other clinoamphiboles, Abbott (1990, 1991) acknowledged that the transferability to amphiboles containing both Fe and Mg is less straightforward. [7]The problem arises because observed frequencies of O-H stretching depend on local structural details that are not preserved by the observed C2/m-averaged structures. [8]It is quite well understood now that the observed frequencies of O-H stretching for simple clinoamphiboles depend mainly on the specific cations occupying the one M(3) site and two M(1) sites coordinated by the hydroxyl oxygen. [9]The four possible ligand compositions, HO Mg3, HO-MgFe, HO-MgFe and HO-Fe3, give rise to four frequencies of infrared (IR) absorption, respectively designated as the A B, C and D bands (Strens 1974, Hawthorne 1981 1983).

[10]A further complication has to do with different arrangements of the ligands associated with the B and C bands. [11]For each of these bands, there are two possible local structures. [12]For the B band, the Fe atom could be at the M(3) site (B' band, Strens 1974) or at one of the otherwise symmetrically equivalent M(1) sites (B band). [13]Observation (Strens 1974, Hawthorne 1983, Skogby & Rossman 1991) suggests that different complexions of the same ligand composition give rise to nearly the same frequency of O H stretching. [14] Similarly, for the C band, the Mg atom could be at the M(3) (C' band, Strens 1974) or one of the adjoining M(1) sites (C band), with practically no detectable difference between the corresponding, observed frequencies of O-H stretching.

[15]Partial to complete disorder of Fe and Mg over the M(1) and M(3) sites is reflected in the geometries of the coordination polyhedra for these sites (Hawthorne 1983). [16]Only for Mg end-member or Fe end-member, amphiboles were observed M(1)-O, M(3)-O, and relevant O-O distances correspond to actual interatomic distances. [17]Otherwise, where both Fe and Mg are present, observed M(1)-O, M(3)-O, and O-O distances are averages that reflect the average Fe-Mg population of all M(1) and M(3) sites. [18]Thus, applying the method of Abbott (1991) directly to a C2/m Mg-Fe amphibole can yield only a single, calculated frequency of O-H stretching, based on the averaged HO-M3 ligand configuration.

[19]The calculated frequency will lie between those calculated for pure Fe and Mg end-member structures; the observed frequencies of A, B, C and D bands are inaccessible because the local configurations of cations are averaged in the observed structure.

[20]In this paper, we use Distance-Least-Squares (DLS) analysis to create realistic geometries for the M(1) and M(3) polyhedra in simple clinoamphiboles containing Fe and Mg. [21]Then, using the method of Abbott (1990, 1991), we calculate frequencies of O-H stretching for DLS structures with different local arrangement of Fe and Mg. [22]The DLS-adjusted local structures are tested by comparing calculated and observed frequencies of O-H stretching. [23]By reproducing reasonable frequencies for the A, B, C and D bands, one goal is to learn more about local deviations from the average structures of simple Fe- Mg clinoamphiboles.

NS-09: Topaz: energy calculations bearing on the location of hydrogen

[1]The major mechanism of solid solution in topaz involves the substitution of hydroxyl for fluorine, OHF, but in natural samples of topaz the fraction OH/(F+OH) does not exceed approximately 0.30 (Rosenberg 1967, Ribbe & Rosenberg 1971, Ribbe 1982). [2]Pure F-topaz and most OH-bearing topaz are orthorhombic, space group Pbnm (Ribbe 1982). [3]In orthorhombic topaz, all hydrogen sites, 8 per unit cell, are symmetrically equivalent, and thus OH and F are necessarily disordered. [4]However, the optical properties of OH-bearing topaz are not always consistent with an orthorhombic symmetry. [5]In a detailed study of the optical properties of two crystals of OH-OH-bearing topaz, Akizuki et al., (1979) showed that depending on the direction of growth, certain sectors are monoclinic or triclinic. [6]After heating to 950C, the low- symmetry sectors became orthorhombic. [7]Akizuki et al., (1979) proposed that the low symmetry of the monoclinic and triclinic sectors is due to the ordering of OH and F.

[8]Using neutron-diffraction data, Zemann et al., (1979) and Parise et al., (1980) determined nearly the same location for hydrogen atoms in topaz referred to space group Pbnm (Table 1, Figs. 1, 2). [9]The fraction OH/(F + OH) was reported as 0.28 and 0.09, respectively, for the crystals used by Zemann et al., (1979) and Parise et al., (1980). [10]In space group Pbnm, the partial occupancy of each hydrogen site would correspond to the bulk value of OH/(F+OH). [11]Refinement of the structure in space group P1 (Parise et al., 1980, Parise 1980) gave a single hydrogen site in nearly the same location as one of the eight equivalent sites determined in Pbnm (Table 1, Fig. 2). [12]The partial occupancy of the single hydrogen site would be eight times the bulk fraction of OH/(F + OH), or approximately 0.72 in the topaz examined by Parise et al., (1980). [13]The ideal P1 structure would be saturated with hydroxyl (i.e., no vacant hydrogen sites) when the bulk fraction of OH/(F + OH) is 1/8. [14] Thus, topaz with a higher OH/(F + OH) fraction, such as for the topaz examined by Zemann et al., (1979), must have either greater symmetry than P1 or more than one kind of hydrogen site in P1. [15]Parise et al., (1980) noted that in the space group Pbnm, hydrogen atoms on adjacent sites related by the (0.01) mirror would be uncomfortably close together, the H-H distance being B5 A, and that avoidance of the H-H repulsion n such a situation could in part be responsible for OH-F ordering in space group P1. [16]Parise (1980, cited in Ribbe, 1982) also noted that hydrogen bonding, O-H...O or O-H...F, may be important in stabilizing hydrogen in the structure, insofar as two H...O distances and one H...F distance are relatively short (2.28 A, 2.29 A, 2.39 A, respectively).

[17]Infrared absorption data (Aines & Rossman 1986) show evidence for two kinds of hydrogen sites, one of which is consistent with observed positions (Table 1). [18]Aines & Rossman (1986) suggested that one hydrogen atom of a pair otherwise related by the (0.01) mirror in Pbnm might be deflected, hence creating a second kind of site.

[19]In the work presented in this paper, energy calculations were used to address two problems relating to reduced symmetry in topaz, (1) the influence of different local orderings of OH and F on the location of a hydrogen atom, and (2) the relative stability of hydrogen atoms in differently ordered local environments. [20]The purpose is to test Parise's H-H avoidance rule (Parise et al., 1980) and scheme of hydrogen bonding (Parise 1980, see Ribbe 1982) and to test the hypothesis of Aines & Rossman (1986) that there are two kinds of hydrogen sites.

NS-10: Gladstone-Dale constants for the major elements in silicates: coordination number, polarizability, and the Lorentz-Lorentz relation

[1]The concept of refractivity of an ion or oxide in crystalline solids is firmly enshrined in the mineralogical literature through the Lorentz-Lorentz (L-L) and Gladstone-Dale (G-D) relationships. [2]The Lorentz-Lorentz law has a theoretical basis, and has been used in a general way by a number of authors, including McConnell (1965) and Anderson (1975), to demonstrate consistency of optical properties in minerals. [3]Batsanov (1961) summarized extensive analyses of refractivity based on the L-L law, and among other variables demonstrated that the refractivity of an ion pair in a silicate depends on the coordination number of the cation.

[4]In contrast to the L-L law, the Gladstone-Dale relation does not appear to have any theoretical basis, but nonetheless has been widely used by mineralogists. [5]In a major series of publications, Mandarino (1976, 1978, 1979, 1981) developed a new series of empirical Gladstone-Dale constants (GDCs) for many constituents improving on those of Larsen Berman (1934) and Jaffe (1956). [6]The GDCs, g_i, relate the mean index of refraction (n) and density (d) of a phase to its composition, expressed as weight fraction of oxide (W_i), by the equation $(n - 1)/d = \quad g_iw_i$.

[7]Mandarino (1979) introduced the concept of "compatibility" as a measure of the degree of agreement between the two sides of the G-D equation. [8]Mineral data for which the agreement lies within 2% he rated as "superior", between 2% and 4%, as "excellent", between 4% and 6%, as "good", between 6% and 8%, as satisfactory, and worse than 8%, as "poor". [9]Mandarino (1981) noted that ortho- and inosilicates seem to require a slightly different set of GDCs than were suited to other compounds, and that garnets required yet another set. [10] Bloss et al., (1983) examined two sets of accurate data obtained by spindle stage collected from an andalusite-kanonaite suite, and from plagioclase samples. [11]By least-squares analysis, they derived GDCs for the component oxides of these minerals, and noted that there was an appreciable difference between their results and those of Mandarino, and that even the GDC for SiO2 ranged from 0.211 for tridymite to 0.188-0.190 for stishovite. [12]Much of the large difference between the results of Bloss et al., and Mandarino can be attributed to the use of the least-squares method by the former authors. [13] There are really only two variables in the andalusite-kanonaite series (those appropriate to the two end-member compositions); hence use of four variables allows spurious minima in the least-squares refinement. [14]Almost any values for SiO2 and Al203 that give the same sum will provide a "good" set of constants.

[15]Jaffe (1988) presented new Gladstone-Dale constants that take into account valency and coordination number for minerals in general and for a variety of silicate structure-types. [16]He found significant variation in GDC with coordination number (for example, from 0.218 for VIAl2O3, to 0.187 for VIAl2O3), and with silicate structure-type (for example, from 0.20 for CaO in scapolite to 0.228 for CaO in epidote). [17]Jaffe (1988) did not describe his method for estimating the GDC, nor the numbers of minerals used to determine each constant, nor did he indicate how successful the resulting compilations are in terms of compatibility, although it is clear from his examples that the new values are an improvement on previous compilations.

[18]Despite the clear limitations recognized by all the above authors in the application of the G-D relation to minerals, the compatibility concept is routinely used to assess the quality of mineralogical data; it has value in this regard, as well as for estimation of density from indices of refraction and results of chemical analysis, and for its intrinsic worth as an empirical but unfounded relationship. [19]The present study was undertaken initially to establish a GDC for Mn2O3 in silicates as part of an investigation of a suite of manganese minerals from Grenfell in New South Wales, Australia (Ashley 1986). [20]It became quickly apparent that the existing GDCs had only limited applicability to layer silicates, and the scope of the investigation widened.

NS-11: Ammonium in zeolitized tuffs of the Karlovassi Basin, Samos, Greece

[1]The ammonium ion is widely distributed as a minor constituent of igneous rocks. [2]It behaves very much like a trace element, substituting isomorphously for potassium in the rock-forming minerals. [3]However, freshly erupted volcanic rocks and their minerals do not contain ammonium. [4]Although it is present in magmas, at atmospheric pressure it is lost by volatilization at the temperature of eruption. [5]Any ammonium present in volcanic and pyroclastic rocks is therefore secondary in origin.

[6]There have been many studies of ammonium in different types of rock, including sedimentary (Williams et al., 1989), igneous (Hall 1988) and metamorphic (Duit et al., 1986), but pyroclastic rocks have not yet been investigated. [7]Zeolitic tuffs are potentially a very favorable host for ammonium because of the cation-exchange properties of zeolites. [8]Moreover, the natural occurrence of ammonium in zeolitic rocks is of more than academic interest, because of the attention now being paid to their value in agriculture and water treatment (Pond & Mumpton 1984, Kallo & Sherry 1988).

[9]This is essentially a reconnaissance study to find out how much ammonium is present in a major occurrence of bedded zeolitic rocks, and to find out if there is any relationship between their ammonium contents and their mineralogy. [10]The material studied is from the Miocene Karlovassi basin on the island of Samos, in the Aegean Sea (Fig. 1).

[11]During the late Miocene, the Aegean region was characterized by the development of ephemeral shallow basins, in which either marine or non-marine evaporites were deposited. [12]The region was volcanically active, and many of these shallow basins were partly filled with volcaniclastic sediments.

[13]The Karlovassi basin is in the western part of Samos and has an extent of approximately 100 km2. [14]During the Miocene, the Karlovassi basin was filled with carbonates, mudstones, ash, cherts and porcellanites. [15]Subsequently, the tuffaceous horizons underwent extensive diagenetic alteration in a saline- alkaline lake environment, resulting in the formation of rocks rich in zeolites, boron-bearing K-feldspar (Stamatakis 1989a) and other authigenic silicates. [16] Many of the tuffs are almost completely composed of authigenic silicates, and contain only minor amounts of detrital minerals. [17]Some are virtually monomineralic with respect to authigenic silicates, especially clinoptilolite or boron-bearing K-feldspar, but the majority are of mixed mineralogy (Stamatakis 1986, 1989b). [18]Three feldspar fractions can be distinguished by X-ray diffraction: primary Na-rich alkali feldspar, primary plagioclase, and secondary K-feldspar. [19]Phyllosilicates are present only in trace amounts, except in the chabazite-bearing rocks, which contain an appreciable proportion of smectite. [20]Carbonate minerals are locally present, but are not abundant.

[21]Petrographic studies and geological mapping suggest that the main source of authigenic silicates was glassy pyroclastic detritus. [22]Zeolites formed first, and a boron-bearing K-rich feldspar formed later, as the salinity and alkalinity of the pore fluids increased. [23]There is a zonal distribution of authigenic silicates, as shown in Figure 2, with enrichment in secondary K- feldspar being confined to the central part of the basin.

NS-12: The timing of alkali metasomatism in paleosols

[1]Paleosols are lithified weathering profiles that can provide information regarding the composition of the atmosphere at the time of weathering. [2]The distribution of iron in paleosols and possibly that of cerium may be used as indicators of the O2 content of the atmosphere during soil formation. [3]The O2 content of the modern atmosphere is so large that Fe2+ released during weathering is usually oxidized quantitatively to Fe3+, and is retained in soil as Fe(OH)3 or Fe3+ oxyhydroxide. [4]Under a low-O2 atmosphere, Fe2+ is not oxidised to Fe3+. [5]It is normally washed out of the upper soil horizons and tends to be reprecipitated as a constituent of one or more Fe2+-bearing mineral in the lower soil horizons where he pH of soil solutions tends to be higher. [6]Several examples of such soils have been discovered in pre-1,900 Ma terranes (Holland & Zbinden 1988 Zbinden et al., 1988, Holland & Belke 1990, Macfarlane & Holland 1990).

[7]Intense chemical weathering of basalt in modern environments produces weathering profiles that are strongly depleted in alkali and alkaline earth elements (e.g., Kronberg et al., 1987). [8]Such profiles are rich in clay mineral such as montmorillonite pyrophyllite, kaolinite and gibbsite. [9]By contrast, the well-characterized Precambrian paleosols are highly enriched in K and Rb. [10] Their mineralogy is typically dominated by muscovite. [11]K and Rb are commonly more enriched in the upper parts of paleosols than the immobile elements Al, Ti and Zr, and may be enriched more than ten times over their concentrations in unweathered parent rocks. [12]Residual enrichment alone thus cannot explain the present alkali contents of these paleosols.

[13]Post-weathering introduction of alkali elements by metamorphic or hydrothermal fluids is a much more likely explanation for the elevated K and Rb contents. [14]A similar origin has been proposed for secondary adularia found by drilling beneath an unconformity in Ohio (Faure & Barbis 1983). [15] To test this hypothesis and to gain further insight into the nature and timing of the transformation of these clay and Al-oxide-rich soils into muscovite-rich metamorphic rocks, we performed Rb-Sr analyses on whole-rock samples of three rather different weathering profiles. [16]Future papers will consider the mobilization of the REE during weathering and metasomatism, and the connection between REE distributions in paleosols and the oxygen content of the atmosphere.

NS-13: Mineralogy of rare-earth-bearing "thucholite", Parry Sound, Ontario

[1]Metal-rich solid pyrobitumens described as "thucholite" occur at numerous localities in southern Ontario. [2]The term "thucholite" was introduced by Ellsworth (1928a) to describe a substance from Conger Township, Parry Sound, Ontario, which consists predominantly of thorium, uranium, carbon, hydrogen and oxygen (Th, U, C, H, O - lite). [3]The Conger occurrence, like many elsewhere, is in a pegmatite dyke that cuts Precambrian gneisses. [4]Shortly after the discovery in Conger Township, thucholite was recorded at Besner mine, Henvey Township, Parry Sound district (Spence 1930). [5]Thucholite was subsequently recorded from Quebec (Ellsworth 1928b, Spence 1940) and from several districts of Ontario, including Algoma (Joubin 1954) Eldorado (Boyle & Steacy 1973), South March (Charbonneau et al., 1975, Jonasson et al., 1977) and Elliot Lake (Ruzicka & Steacy 1976, Stevenson et al., 1990).

[6]The occurrence of thucholite in several pegmatite dykes has suggested to some workers a magmatic origin for the carbon (Ellsworth 1928a, 1932, Barthauer et al., 1953, Mueller 1969). [7]However, at the Besner mine, the pegmatite also contains oil and asphalt-like bitumen in cross-cutting fractures, and thucholite tends to occur in the vicinity of the oil-bearing zones (Spence 1930). [8]Given that there are numerous oil shows, and some oil production, in the Lower Paleozoic of Ontario (e.g., Becker & Patton 1968), it is very likely that petroleum fluids percolated downward from the Lower Paleozoic rocks into underlying Precambrian basement, and were polymerized (solidified) by radiation from nearby radioactive minerals in the pegmatite. [9]It is known that some petroleum samples from Ontario leave a solid residue that is permanently active (Burton 1904).

[10]Thucholite from the Parry Sound district has been subjected to several geochemical studies because of its abnormal content of heavy metals. [11] Determination of metals in thucholite ash (Ellsworth 1928a, Barthauer et al., 1953, Hoekstra & Fuchs 1960), X-ray spectroscopy (Faessler 1931) and infrared absorption spectrophotometry (Hoekstra & Fuchs 1960), and X-ray diffraction (Kelley & Kerr 1958) have contributed to our knowledge of thucholite chemistry. [12]The high uranium content of the Parry Sound thucholite made it a subject of early studies in radiometric age dating (Faessler 1931, Muench 1937, Nier et al., 1941). [13]The detailed chemical study by Hoekstra & Fuchs (1960) has since shown that thucholite samples can be divided into three populations, each particularly rich in uranium, thorium, or the cerium group of rare earths. [14]Uranium thucholite is known to contain uraninite inclusions or to have a core of solid uraninite (Spence 1930, Ellsworth 1932; see examples from elsewhere in Parnell & Eakin 1987). [15]Thorium-rich thucholite typically contains thorite or thorianite (e.g., Parnell 1988). [16]The distribution of heavy metals in a rare-earth thucholite has not been previously described. [17]The present paper reports an investigation of rare-earth-enriched thucholite from the Besner mine, using combined back-scattered electron imagery (BSE) and electron-microprobe techniques. [18]The study reports the distribution of the major rare-earth components (present at above the 0.05 wt.% level, the limit of the analytical facility). [19]The elements detected at this level are those recorded by Faessler (1931) and Hoekstra & Fuchs (1960) to be relatively abundant: Ce, Nd and La. [20]Qualitative analysis indicated that other elements also are present. [21]The study forms part of a wider investigation of ore- mineral inclusions in metalliferous bitumens and pyrobitumens.

NS-14: A gahnite-garnet retrograde reaction from the pinnacles deposit, Broken Hill, New South Wales, Australia

[1]The spinel gahnite represents the zincian end-member of the gahnite-hercynite solid-solution series [(Zn,Fe,Mg)AlOJ. [2]Although gahnite is relatively rare in nature, it has been reported in association with metamorphosed massive sulfide deposits (Plimer 1977, Williams 1983, Sheridan & Raymond 1984, Spry & Scott 1986, Spry 1987a, b). [3]The high Zn content of the spinel, together with its hardness (8) and stability in metamorphic rocks, make it a potential indicator mineral in base-metal exploration programs (Sheridan & Raymond 1984, Spry & Scott 1986). [4]Several theories have been proposed for the formation of gahnite in metamorphic rocks. [5]These include the desulfurization of sphalerite (Sangster & Scott 1976), the breakdown of Zn-bearing silicates such as biotite (Dietvorst 1980) and staurolite (Stoddard 1979) during prograde metamorphism, and the metamorphism of opaline silica and hydrothermal clays with adsorbed Zn and zincian carbonate (Plimer 1988).

[6]Quartz-gahnite rock is the most common gahnite-bearing lithology in the Willyama Super-group, New South Wales; other rock types include psammitic to pelitic metasediments and quartz feldspar-biotite-garnet-gahnite gneisses (Barnes et al., 1983). [7]Gahnite is commonly observed as a gangue mineral in the base-metal ores of the Broker Hill deposit, within the Willyama Supergroup (e.g., Segnit 1961 Richards 1966, Plimer 1976, 1977, Spry 1978, i984, 1987a, Barnes et al., 1983). [8]In the main Broken Hill lode, there are at least two distinct gahnite-bearing assemblages: quartz-gahnite-pyrrhotite-galena-garnet- biotite (staurolite, muscovite, il-

menite, sphalerite) and garnet-biotite - chlorite - sphalerite - gahnite - galena - pyrrhotite - quartz (ilmenite); muscovite, chlorite and staurolite are retrograde minerals (Spry 1978). [9]This contribution documents one particularly unusual occurrence of gahnite from the Pinnacles Mine Sequence, New South Wales, in which retrograde reactions in sulfur-poor quartz - garnet - gahnite - biotite pelites (sillimanite-deficient) have produced a garnet rim on grains of gahnite. [10]The association of retrograde garnet and prograde gahnite in sillimanite- and sphalerite-deficient rocks has not been described previously and allows some speculation on metamorphic conditions in the Broken Hill area.

NS-15: Structural state of the K-feldspar in the Butler Hill-breadtray Granite, St. Francois Mountains, Southeastern Missouri

[1]The St. Francois Mountains of southeastern Missouri represent the best exposure of Precambrian basement in the mid-continent region of the United States. [2]Over an area of nearly 1000 square kilometers, erosion has removed the Paleozoic cover and exposed a complex series of Proterozoic silicic volcanic and granitic plutonic rocks that are interpreted to be remnants of a series of collapsed calderas (Sides et al., 1981, Kisvarsanyi 1981, Kisvarsanyi et al., 1981).

[3]The Butler Hill - Breadtray granite is the largest pluton exposed in the St. Francois Mountains complex (Fig. 1). [4]This pluton is interpreted to have formed as a subvolcanic massif that crystallized beneath a cover of its own volcanic ejecta (Sides et al., 1981, Kisvarsanyi 1981, Kisvarsanyi et al., 1981). [5] Pratt et al., (1979) mapped the Butler Hill Breadtray granite as a single pluton with two distinct facies separated by a gradational contact: the Butler Hill Facies constitutes the northeastern third of the exposure, whereas the Breadtray Facies constitutes the southwestern two-thirds. [6]The Butler Hill Facies is generally medium- to coarse-grained, whereas the Breadtray Facies is distinctly finer-grained. [7]Based on this textural variation along with systematic variations in the modal mineralogy, the Butler Hill is generally interpreted to represent the main phase of the magma body, whereas the Breadtray is interpreted to be the roof facies (Sides 1980, Sides et al., 1981). [8]Pratt et al., (1979) also mapped several small, isolated exposures of granite as parts of the Butler Hill - Breadtray pluton. [9]The largest of these outlying exposures, sometimes referred to as the Hawn Park pluton, is located approximately 20 km northeast of the main exposure of the Butler Hill - Breadtray granite.

[10]Field relationships among the various Proterozoic volcanic and plutonic units exposed in the St. Francois Mountains suggest that the entire complex is a roughly tabular sequence that has been tilted to the west-southwest and subsequently beveled by erosion (Bickford et al., 1977, Sides et al., 1981). [11] Based on variation in the major-element bulk chemistry, Sides (1980) concluded that the Butler Hill-Breadtray granite has been tilted approximately 10 in the S68.3W direction exposing the structurally lowest and least differentiated part of the pluton to the northeast. [12]From this chemical variation within the pluton along with petrographic and field relationships with the surrounding volcanic units, Sides (1980) inferred that the Breadtray granite exposed along the southwestern intrusive contact may have crystallized beneath as little as 1 to 2km of volcanic over, whereas the northeastern exposures of the Butler Hill granite may represent depths of crystallization as great as 10 km.

[13]The most abundant mineral throughout the Butler Hill Breadtray granite is microperthitic K-feldspar. [14]The factors that control the structural state of plutonic K-feldspar are numerous and varied (Martin 1974, Stewart & Wright 1974 Parsons & Brown 1984, Brown & Parsons 1989) and there does not yet seem to be a consensus as to which, if any, of these factors should be dominant in any particular pluton. [15]Nevertheless, K-feldspar structural state has been shown to vary systematically in a number of plutonic bodies (Wright 1964, Tilling 1968, Parsons & Boyd 1971 Bychkov et al., 1977, Cherry & Trembath 1978, Jiranek 1982), and this variation has proved useful in deciphering the geometry and geological history of those plutons. [16]If the model of Sides (1980) for the emplacement and subsequent exhumation of the Butler Hill - Breadtray granite is correct, one might expect a systematic variation in K-feldspar structural state from southwest to northeast across the presently exposed parts of this pluton. [17]The purpose of this study was to determine whether any such variation could be detected by X-ray powder diffraction.

NS-16: Routine trace-element capabilities of electron-microprobe analysis in mineralogical investigations: an empirical evaluation of performance using spectrochemical standard glasses

[1]Quantitative information on the trace elements present in minerals is needed for a variety of applications, including: 1) the provision of constraints on petrogenetic hypotheses through studies of trace element partitioning behavior in natural and experimental systems, 2) the search for indicator elements in the minerals of potential host-rocks to mineralization, and 3) the economic evaluation of orebodies whose viability may depend upon the presence of trace metals, such as refractory gold, in specific host-minerals.

[2]Microbeam techniques (for example, electron, ion and proton microprobes, high-resolution SIMS, and synchrotron X-ray fluorescence) are the only ones able to obtain such information in situ. [3]Each has its advantages and disadvantages. [4]The superior spatial resolution of the electron microprobe, however, means that this instrument must be used where the minerals are fine grained, intimately intergrown or complexly zoned, even though detection limits are generally poorer than with the other techniques.

[5]A concentration of 100 ppm commonly is taken as the typical limit of detection for electron-microprobe analysis using wavelength dispersion (Reed 1975, Goldstein et al., 1981, Newbury et al., 1986). [6]The literature contains many reports demonstrating that such levels and better (down to 10 ppm) can be determined by these techniques (Goldstein 1967, Buseck & Goldstein 1969, Smith 1971, Schneider 1972, Koppel & Sommerauer 1973, Rao 1973, Hewins & Goldstein 1974, Bishop et al., 1978, Hervig et al., 1980, Bizouard 1982, McKay & Seymour 1982, Solberg 1988). [7]Such results, however, have been obtained for only a limited number of elements in specific minerals and, in general, have not called upon independent methods of analysis for verification. [8]In most cases, the analytical procedures have been far from routine.

[9]The aim of the present study has been to evaluate the performance of the electron microprobe for a wide range of trace elements (from Sc to U) using procedures that are routinely available and readily accessible to the average user in any mineralogically oriented laboratory. [10]Since "...all results are a matter of opinion rather than fact..." (Lunddl 1933), the "true results" have been taken to be those for which a variety of other methods show agreement (Myers et al., 1976), and the performance of the electron microprobe has been judged by comparison with these.

NS-17: Massive sulfides with fluid-inclusion-bearing quartz from a young seamount on the East Pacific Rise

[1]Seafloor sulfide deposits have been discovered at many sites along the world's mid-ocean ridge system, as well as atop several deep-sea volcanoes (Rona 1988). [2]Known sulfide deposits from seamounts are less abundant than from ridge crests, probably as a consequence of sparse sampling. [3]Those from young seamounts near the East Pacific Rise (EPR) have been described and analyzed by Alt and co-workers (Alt et al., 1987, Alt 1988a,b) and Hekinian & Fouquet (1985). [4]A silica sulfide sulfate deposit from Axial Seamount on the Juan de Fuca Ridge has been studied extensively by Hannington Scott (1988). [5]Other examples are from a submarine volcanic arc seamount (Urabe et al., 1987) and from a Mediterranean seamount (Minniti & Bonavia 1984). [6] Hydrothermal deposits devoid of sulfides occur at Loihi seamount (Malahoff el al., 1982), Red seamount on the EPR at 21N (Alt 1988a) and other seamounts in the Pacific and Mediterranean (e.g., Exon Cronan 1983, Vanko et al., 1984, Varnavas et al., 1988, Uchupi and Ballard 1989). [7]The relative importance of submarine hydrothermal activity associated with seamounts is unknown. [8] However, in terms of net crustal cooling, net amount of seawater reacted with crustal rocks, and potential for creating seafloor sulfide deposits, seamount could play a important role in global budgets (Lonsdale et al., 1982, Batiza 1982).

[9]The present paper gives results of petrographic and geochemical studies on hydrothermal rocks dredged from a young volcanic seamount near the East Pacific Rise at 1409'N. [10]Rock types recovered in a dredge haul of the seamount summit included abundant earthy, low-density reddish orange crusts and poorly consolidated sediments, several denser and harder pieces of massive sulfide and rare crusts coated by euhedral crystals of atacamite. [11] These samples are described, and results of partial chemical, X-ray diffraction, and fluid inclusion analyses are presented.

NS-18: Thermoluminescence spectra of minerals

[1]Thermoluminescence (TL) is a sensitive (technique for studying defects and defect concentrations in insulators. [2]Naturally-occurring crystals of rock- forming minerals contain both intrinsic effects and extrinsic impurities. [3]The presence of impurities in concentrations of the order of p.p.b. to p.p.m. is, for example, responsible for the colours exhibited by natural forms of transparent minerals such as quartz and fluorite. [4]TL spectra provide important information on the nature of both intrinsic and extrinsic defects, and on their spatial relationships within crystals, by allowing both temperature-dispersive separation of different traps (defects) and wavelength-dispersive separation of radiative recombination centres. [5]A review of the potential information that can be deduced from TL spectra is given by Townsend and Kirsh (1989). [6]There is a variety of techniques for studying defects and not all methods reveal the same defects. [7]Luminescence methods of TL, CL (cathodoluminescence) and PL (photoluminescence) are complementary in that TL records metastable defects, dispersed throughout the bulk of the material, with charge states within the band gap. [8]By contrast, CL provides data from transient defects, in a thin surface layer, after ionisation within the lattice.

NS-19: Composition of fluids in quartz: discrimination of magma pulses in a Caledonian Granitoid

[1]The important role of fluids in mineralisation and petrogenesis has been recognised for a long time and information on their composition has until recently been obtained from optical studies of fluid inclusion. [2]Chemical analysis of the fluids trapped inside inclusion has been achieved both by crushing the sample under a solvent and analysing the leached cations and by thermal decrepitation of the sample under vacuum followed by manometry and gas chromatography/mass pectrometry. [3]Most analytical studies on fluids have concentrated on mineralised rocks and investigations into the role of fluid in ore transport. [4]This work describes the quantitative determination of H2O CO2, Na and K in quartz and its application to the petrogenesis of a multiphase Caledonian granitoid which highlights a strong link between the composition of fluids in quartz and whole rock trace-element geochemistry.

NS-20: Deformation textures in pyrite from the Vangorda Pb-Zn-Ag Deposit, Yukon, Canada

[1]The Vangorda deposit is a 7.1 million tonne, SEDEX-type massive sulphide orebody in the Anvil Pb-Zn-Ag District, Yukon Territory, Canada. [2]The deposit has a combined Pb + Zn grade of 7.7%. [3]It has been polydeformed and polymetamorphosed under mid-greenschist facies conditions. [4]The Vangorda orebody is shallowly southwesterly dipping, with complex and folded lenses of massive and disseminated sulphides and barite approximately 900m long, 100m wide and varying in thickness from 20 to 60m. [5]The orebody is currently being mined in a 10000 tonne per day open pit operation by Curragh Resources. [6]The deposit consists of lenses of baritic-pyritic massive sulphides, pyritic massive sulphides, pyritic quartzites, and ribbon banded carbonaceous quartzites in quartz-chlorite-muscovite phyllites. [7]Five distinct sulphide lithofacies with varying modal abundances of pyrite have been identified. [8]Pyrite within these display a variety of brittle and ductile deformation features, together with recrystallisation and annealing textures.

[9]Pyrite in many deformed and metamorphosed ore-bodies, as well as in controlled experiments has been shown to deform by brittle mechanisms over a wide range of geological conditions. [10]It has further been demonstrated that both experimentally and naturally deformed pyrite also deforms by crystal plastic mechanisms, and diffusive mass transfer coupled with grain boundary sliding. [11]Cox experimentally determined the onset of crystal plastic mechanisms in pyrite to occur at approximately 450C at 300 MPa. [12]Dynamic recrystallisation, though not a widely reported feature in naturally deformed pyrites, has also been found to occur. [13]This paper examines deformation and annealing textures in pyrite from the Vangorda deposit. [14]Data for this study comes from logged diamond drill holes and from detailed mapping and sampling of the open pit.

NS-21: A supposed sovite from Oldoinyo Lengai, Tanzania: result of extreme alteration of alkali carbonatite lava

[1]Oldoinyo Lengai, situated in the Rift Valley of northern Tanzania, is the world's only active carbonatite volcano. [2]The main pan of the volcano is built of yellow nephelinitic and phonolitic tuffs and agglomerates (YTA or Unit 1) and younger black nephelinitic tuffs and agglomerates (BTA or Unit 3) (Dawson 1989). [3]Another less-extensive formation that will be referred to below is the so-called Footprint Tuff, that post-dates BTA (Hay, 1989).

[4]During the 1960 survey of Oldoinyo Lengai, I collected an angular block of fine-grained calcite-rich rock (BD83) embedded in Unit 3 nephelinitic agglomerate on the lower eastern slopes of the volcano. [5]It was identified as a calcite carbonatite by the Tanganyika Geological Survey, and I have reported it as sovite in accounts of the geology of the volcano (Dawson, 1962, 1989). [6]A re-examination of this specimen has been prompted in view of its potential relevance to the origin of alkali carbonate liquids, similar to those erupted in historic times from Oldoinyo Lengai. [7]Gittins (1989) has argued that natrocarbonatite arises by sovite fractionation from an original mixed alkali-calcium carbonate magma.

[8]Because BD83 is texturally similar to both modern and older, partly-altered natrocarbonatite lavas from the volcano, the investigation was extended to a study of the groundmass carbonate and opaque phases of a party altered natrocarbonatite GA47, collected from a down-faulted succession within the crater, the petrography and bulk chemistry of which have been given by Dawson et al., (1987). [9]Also examined in this study, are the groundmass phases in another party-altered lava sample (BD4162) collected from the same locality as GA47 and petrographically identical.

NS-22: The stabilities of secondary tin minerals: abhurite and its relationships to Sn(ii) and Sn(iv) oxides and oxyhydroxides

[1]The corrosion of tin in saline environments usually results in the formation of stannous and stannic oxides, although chloride-containing tin phases have been reported on numerous occasions. [2]Abhurite, originally found in surface blisters on tin ingots recovered from a wreck in the Red Sea (Matzko et al., 1985), is one of the latter.

[3]Numerous preparations of tin hydroxychloride have appeared, dating back some decades (Ditte, 1882; Carson, 1919). [4]A number of stoichiometries, including SnCl2.4SnO.6H2O, SnCl2.SnO.4H2O, 2SnCl2.3SnO.5H2O, 3SnCl2.5SnO.3H2O and 2SnCl2.7Sn(OH)2, were reported and Britton (1925) found a range of compositions from Sn(OH).SnCl at pH 1.9 to Sn(OH).SnCl at pH 7. [5]More recent investigations have pointed to the fact that only one basic tin(II) chloride exists and that the phases isolated by previous workers are mixtures of basic tin chloride and hydrous tin oxide. [6]Randall and Murkami (1930) prepared 'SnCl(OH) (s)' under conditions similar to those specified by previous investigators, although the degree of hydration of the phase was uncertain. [7]Donaldson et al., (1963) prepared a salt of composition Sn4Cl2(OH)6; the synthesis has been reported to yield other substances. [8]Hayek (1933) formulated the compound he obtained as Sn(OH)2.SnCl2, while Randall and Murkami (1930) used the formula SnOHCl.H2O to derive the free energy of formation of the salt. [9]Ichiba and Takeshita (1984) suggested that the true composition was Sn3Cl2(OH)2O and this is the stoichiometry which has been attributed to abhurite.

[10]However, von Schnering et al., (1981) have determined the single-crystal X- ray structure of the basic tin(II) chloride and showed that the correct formula is Sn2,Cl;h(OH)I40h. [11]Nevertheless, this has been overlooked by recent investigators. [12]Attention is here drawn to the fact that abhurite and the synthetic phase Sn21Cl,h(OH),4Oh are identical. [13]Through repeat synthesis and comparison of physical and analytical data and results, it was demonstrated that all preparations of the basic tin(II) chloride result in the above compound. [14]Discrepancies in previous formulations may be the result of the presence of tin(II) oxychlorides and adsorbed water; the latter is well- known for hydrous Sn(ii) oxides. [15]If the product is for example dried at temperatures above 368K, dehydration to Sn9Cl407 occurs, with subsequent decomposition of other tin(ii) oxychlorides. [16]Hydrolysis of stannous ion in aqueous, chloride-containing solutions gives abhurite as the sole oxyhydroxide at low pH. [17]While a number of stoichiometries have been proposed for such hydrolysis products in the past, it is now clear that solids obtained were almost invariably mixtures of abhurite and an oxychloride formed as an artefact of the synthetic and isolation procedures adopted.

[18]Abhurite was originally described as an alteration product of tin ingots recovered from a shipwreck in the Red Sea (Matzko et al., 1985). [19]Chemical analysis gave a stoichiometry of Sn3CL2(OH)2O. [20]The mineral was shown to be rhombohedral, space group R3m, R3m or R32, with a = 10.0175(3), c = 44.014(2)A, Z = 21 (for the formula given above), Dc = 4.35 and Dm = 4.29 g cm-3. Sn21Cl16(OH)14O6 is rhombohedral, space group R32, with a = 10.018(1), c = 44.030(2)A, Z = 3, Dc = 4.417(1) and Dm = 4.42g cm-3. [21]These crystallographic data are virtually sufficient to establish the identities of the natural and synthetic phases. [22]Extensive listings of powder X-ray diffraction data provided in the two papers further show that abhurite has the indicated formula.

[23]It would be a difficult task to derive the stoichiometry of abhurite by chemical analysis alone. [24]Nonetheless, the determination of the single-crystal X-ray structure puts the composition of abhurite beyond doubt. [25]It is interesting to note that Sn2,CL,6(OH),40h can also be shown to be the correct composition of the basic tin chloride made by Carson (1919) through the decomposition of SnCl2 in dilute KOH(aq). [26]Comparison of the reported analytical data with that for Sn2,CL,h(OH),40h indicates this is the correct formula, rather than 3SnCl2.5SnO.3H2O as originally suggested.

[27]For some time we have been interested in describing the corrosion mineralogy of archaeological metal artefacts. [28]The aim has been to provide a chemical model for the corrosion products and to use it to develop methods for consolidation and restoration. [29]Since tins, leads and pewters are frequently recovered from the archaeological content, these elements are of particular interest.

[30]A number of oxides and oxyhydroxides of Sn(ii) and Sn(IV) have been reported as corrosion products of archaeological tin, principally from non- saline environments. [31]However, abhurite appears to be a common corrosion product of archaeological tin recovered from sea water. [32]We have thus determined its stability constant at 298.2K in order to assess its likely mode of formation in the supergene environment in relation to other Sn(II, IV) oxides and oxyhydroxides. [33]The results of the study are reported below.

NS-23: Sulphide mylonites from the Renstrom Vms Deposit, Northern Sweden

[1]Mylonites are rocks found in shear zones where intense plastic deformation has resulted in grain size reduction. [2]There are various microscale processes that serve to accommodate the strain in these shear zones; these include pressure solution, dislocation glide, dislocation creep, grain boundary sliding, deformation twinning and dynamic recrystallisation. [3]The types of process that are operative are largely dependent on temperature and strain rate (Knipe, 1989), and also to a lesser extent, on confining pressure, fluid activity and permeability within the deformation zone. [4]Most

volcanogenic massive sulphide (VMS) deposits now exposed on land have been subjected to some degree of metamorphism and deformation, but despite this, many deformation textures in the sulphides are either not recognised or not reported, and may have been misinterpreted as primary textures.

[5]Experimental work has provided much of the information about deformation mechanisms within sulphide minerals and the resulting microtextures. [6]It has been shown that the strength of sulphides decreases with an increase in temperature, and is largely independent of confining pressure (Clark and Kelly, 1976). [7]Cox et al., (1981) showed that pyrite can deform by dislocation processes at temperatures between 400 and 700C. [8]McClay and Ellis (1983,1984) introduced the idea that pressure solution was an important deformation mechanism for pyrite under conditions of greenschist facies metamorphism. [9]Cox (1987) investigated flow mechanisms in sulphide minerals and concluded that dislocation creep is an important flow mechanism in many sulphide minerals in a range of crustal environments. [10]However, it is most commonly observed as a deformation mechanism under conditions of medium grade metamorphism. [11]The weaker sulphides, such as galena, dynamically recrystallise during dislocation creep at temperatures at least as low as 250C, chalcopyrite recrystallises at about 300C at natural strain rates; whilst at similar low temperatures sulphides such as pyrite and arsenopyrite may deform by brittle failure and cataclastic flow, particularly if effective confining pressures are low.

NS-24: Low-pressure corona textures between olivine and plagioclase in unmetamorphosed gabbros from Black Hill, South Australia

[1]Reaction coronas between olivine and plagioclase are a common feature of many gabbroic rocks. [2]In general, such coronas formed at high pressures and are associated with garnet and/or spinel plus clinopyroxene as reaction products (see Nishiyama, 1983 for a review). [3]Coronas are usually described from metamorphosed gabbros and consequently have often been interpreted to be associated with protracted cooling during the metamorphic event (e.g., Mongkoltip and Ashworth, 1983). [4]However, there has been some considerable debate over this metamorphic versus igneous origin (e.g. Joesten, 1986a and b; Ashworth, 1986).

[5]Here we report on new symplectitic reaction coronas between olivine and plagioclase in gabbroic rocks from Black Hill, South Australia. [6]The gabbroic rocks at Black Hill (about 85 km E of Adelaide) intruded at relatively low pressures after the end of regional metamorphism and have not experienced any metamorphism subsequently and are thus pertinent to the debate mentioned above. [7]The physicochemical conditions during corona formation are not only different from many of those described in the literature, but their formation is well constrained by the conditions during crystallisation of the magma as the coronas must have formed during initial igneous cooling.

NS-25: Petrogenetic implications of garnets associated with lithium pegmatites from SE Ireland

[1]Garnets are common in many metamorphic rocks, particularly those of pelitic composition, and skarns, but are not abundant in igneous rocks. [2]They are rarely found in volcanic or mafic rocks but often occur as acccssories in peraluminous granites (e.g., Sutherland, 1982), aplites (e.g., Miller and Stoddard, 1981; du Bray, 1988; Harrison, 1989), syenites (e.g., Sutherland, 1982), aplites (e.g., Whitworth and Feely, 1989) and granitic pegmatites (e.g., Cerny and Hawthorne, 1982; Manning, 1983; Baldwin and von Knorring, 1983).

[3]The origin of garnets in granitic rocks has long been a subject of debate and was recently reviewed briefly by Stone (1988). [4]Essentially, three modes of origin have been proposed; assimilation of pelitic material (Green and Ringwood, 1968; Allan and Clarke, 1981), high-pressure phenocrysts or xenocrysts transported to higher levees (Green and Ringwood, 1968: Green, 1977) and crystallisation at low pressure from a peraluminous fluid (Miller and Stoddard, 1981). [5]Furthermore, changes in the chemistry of garnets reflect the chemical evolution of the phase from which they crystallised and hence have led to a deeper insight into the origin and evolution of some granitic complexes (e.g., du Bray, 1988; Stone, 1988; Harrison, 1988). [6]The presence and relative proportions of various garnet and members permit conclusions to be drawn about possible petrogeneces of granitic magma and also the approximate depth of formation. [7]In general, almandine-rich garnets are associated with less well-evolved granitic rocks, possibly generated at greater depths than more evolved granites which contain high-spessartine garnets. [8] This information, combined with stable isotope and fluid inclusion data may give further insights into the petrogenesis of Li pegmatite magmas. [9] Accordingly, this paper documents the occurrence, distribution and chemistry of garnets hosted by spodumene pegmatites, aplites and chists from the Aclare Li pegmatite prospect, SE Ireland (Fig. 1). [10]Fifty five analyses of garnet were performed on a Cambridge Instruments GeoScan IV microprobe operating in ED mode using an accelerating voltage of 15 kV with a livetime of 100 seconds. [11]Data were automatically reduced using the ZAF4 FLS+ software of Link Analytical Systems. [12]Representative analyses of garnets found in rocks at Aclare are presented in Table 1, along with their formulae calculated on the basis of 24 oxygens. [13]Textural and chemical data are integrated with the results of previous experimetal, laboratory and field studies in order to further constrain the petrogenesis and P-T-X evolution of the Aclare Li deposit as described by Whitworth and Rankin (1989), Whitworth et al., (1989), and McArdle and Kennan (1987).

NS-26: The rheology of faults triggered by the olivine-spinel transformation in Mg2GeO4 and its implications for the mechanism of deep-focus earthquakes

[1]Deep-focus earthquakes have been a paradox since their discovery 70 years ago. [2]Their seismic characteristics are virtually indistinguishable from those of shallow earthquakes, yet experimental evidence and theoretical considerations demonstrate that brittle shear fracture and stick-slip frictional sliding, the physical mechanisms responsible for shallow earthquakes, cannot operate at the high pressures at which deep earthquakes occur. [3]Thus, it has been argued almost since their discovery that deep earthquakes must be the result of a different process. [4]Kirby (1987) suggested that some peculiar aspects of faulting at high temperatures and high pressures in tremolite and at low temperatures and low pressures in H2O ice may be relevant. [5]He argued that incipient transformation to the more dense higher pressure assemblage may have triggered faulting, although the actual mechanism by which this process could occur remained unclear.

[6]Observations of microstructures in Mg2GeO4 olivine polycrystals that exhibited anomalous faulting behavior at high pressure (0.8-2.2 GPa) led to the proposal that faulting occurs by incipient transformation of metastable olivine to very fine-grained spinel in lens-shaped Mode-I microanticracks that organize themselves into throughgoing faults on which sliding occurs by superplastic deformation of the fine-grained spinel (anticrack theory of phase- transformation

faulting; Green & Burnley 1989, Burnley et al., 1991). [7]The same microstructures and anomalous faulting behavior also have been observed at 14 GPa in association with the ß phase transformation in (Mg,Fe)2SiO4 olivine in peridotite of appropriate composition for the Earth's mantle, supporting the hypothesis that this is the mechanism of deep-earthquake faulting (Green et al., 1990). [8]Subsequent investigations of the faulting phenomenon in ice have revealed microstructures similar to those present in the germanate specimens (Kirby et al., 1991).

[9]Despite its remarkable similarity to brittle shear fracture, several aspects of the anomalous faulting behavior in Mg2GeO4 indicate that it is not a brittle phenomenon. [10]Principal among these are the following. [11](1) There are no detectable acoustic emissions prior to failure (Green et al., 1992). [12](2) The faulting stress is independent of confining pressure (Burnley et al., 1991). [13](3) Faulting occurs only in a narrow temperature window (Burnley et al., 1991). [14](4) Very fine-grained spinel is present in fault zones (Green & Burnley 1990, Burnley et al., 1991).

[15]The principal goal of this study was to measure the sliding resistance on faults generated by the anticrack mechanism as a function of confining pressure. [16]The observed pressure and rate dependence of the sliding stress indicate that sliding is not controlled by friction. [17]It appears that sliding occurs by a viscous process induced by the extremely fine grain size of the high density phase that grows in the anticracks and is incorporated into the fault zone during faulting. [18]Thus, the underlying physics of the anticrack mechanism of phase-transformation faulting (and, by extension the mechanism of deep-earthquake faulting) are distinct from those involved in brittle shear failure.

NS-27: A footwall system of faults associated with a foreland thrust in Montana

[1]There are several approaches that have been used to elucidate the structure and kinematic evolution of a thrust fault system. [2]They include geometric modelling, kinematic modelling, detailed field studies, section balancing (forward and backward modelling) and seismicity distribution studies.

[3]Several recent papers point out a very important field observation that a considerable amount of deformation occurs off the main thrust fault in a contractional deformation (e.g., Holm et al., 1988, Protzman & Mitra 1990). [4]This is in contrast to the first-generation geometric and kinematic models of thrusting which set up models with a rigid footwall (e.g., Suppe 1983). [5]Second-generation models now admit to both hangingwall and footwall deformation at ramps on thrust faults (Kilsdonk & Fletcher 1989).

[6]This paper compares a very well-exposed field example of a thrust fault system with a recent study of the distribution of aftershocks associated with movement on a thrust fault. [7]Then, using the field data as a basic geometric constraint, a simple physical model analogue is set up to show a possible kinematic evolution of such a system.

NS-28: The interplay between fluids, folds and thrusts during deformation of a sedimentary succession

[1]Models proposed for the reactivation of faults (e.g., Sibson et al., 1975, 1988) indicate that reshear along a fault occurs in a series of stick-slip movements and that there is an intimate association between fault reactivation and the migration of large quantities of fluid along the fault.

[2]These ideas are broadly compatible with the conclusions drawn from a detailed study of composite veins formed parallel to the bedding planes in the Wenlock slates north of Llangollen, North Wales, which indicate that as the sedimentary succession compacted and was subjected to a tectonic compression the pore fluid pressure increased until it was of sufficient magnitude to cause the formation or reactivation of a bedding plane thrust by hydraulic fracturing. [3]A study of these veins indicates that movement on the thrust drove the fluids from the slip zone and the resulting drop in fluid pressure caused the thrust to lock up temporarily. [4]Continued action of the applied stress caused the fluid pressure to increase again until the conditions for hydraulic fracturing were reestablished and the process was repeated.

[5]It is argued that a similar process will accompany the amplification of large folds in a sedimentary pile. [6]The folds will grow incrementally by a series of stick-slip movements along the bedding plane associated with the build up and release of fluid pressures. [7]The distribution of mean stress within and around a fold has also been determined theoretically (Summers 1979) and it is clear that during the early stages of fold amplification the mean stress gradients draw fluids into the growing fold from the surrounding rock. [8]At some critical point in the fold's amplification the gradient is reversed and further fold growth drives fluids out of the fold.

[9]Thus the combined effect of thrust and fold development considerably influences the migration and concentration of fluids in a sedimentary sequence. [10]It is suggested that the 'pumping' effect of both these structures will in turn help to generate other folds, thrusts and fractures.

[11]The paper begins with a brief discussion of the ideas that have led to the association between high fluid pressures and thrusting and this is followed by a description of field evidence that support this.

NS-29: Constant bed-length folding: three-dimensional geometrical implications

[1]During the analysis of a wide variety of tectonic structures (thrusts, normal faults, folds) the assumption is frequently made that the length of deformed beds, measured in cross-section, equals the length of the beds in the pre- deformation state. [2]Although the main justification for making this assumption is usually one of analytical convenience, the property of constancy of bed- length is implied in the flexural folding and neutral Surface folding models. [3]In natural folds, the condition of constant bed-length will be approached in the case of parallel (class 1B) folds produced in strongly anisotropic layered sequences or in thin beds with high relative competence.

[4]The application of this assumption to the situation involving several beds in a cross-section through a structure imposes severe limitations on the possible two-dimensional geometry of the structure. [5]This is the basis of the well- known technique of cross-section balancing.

[6]This paper examines the three-dimensional implications of the constant bed- length folding model to discover the range of possible fold forms which can result from this mode of deformation. [7]Once these feasible fold geometries are defined from a theoretical standpoint, attempts are made to devise forms of analysis which allow these special fold geometries to be recognized amongst natural structures. [8]This, in turn, allows conclusions to be drawn regarding the presence or absence of bed stretching associated with particular natural fold structures.

NS-30: Three-dimensional finite strain from crinoid ossicles

[1]In his seminal publication on oolite deformation in the South Mountain fold, Cloos (1947) suggested that crinoid stems could be used to evaluate and quantify strain in naturally deformed rocks. [2]He recognized that crinoid disks, or ossicles, often are deposited parallel to bedding, and that since the ossicles are initially circular in cross-section, the shape and orientation of the strain ellipse in the bedding plane can be measured directly. [3]He also illustrated that three-dimensional strain can be calculated in favorable circumstances, namely when whole crinoid stems lying within bedding are oriented parallel to the principal finite strain axes. [4]In practice, however, these conditions are rarely satisfied, and crinoids generally have been used to quantify only the two- dimensional strain within the bedding plane (Hellmers 1955, Breddin 1956a,b, Kurtman 1960, Nissen 1964, Engelder & Engelder 1977, Faill 1977, Engelder 1979, Oertel et al., 1989).

[5]Two sources of potential error in the simple two-dimensional analysis are related to the assumption of initial circular shape of the ossicles. [6]First, although most crinoid stems are indeed circular in cross-section, several species have originally elliptical profiles (Nissen 1964, Moore & Teichert 1978, Spratt 1987). [7]Second, even for initially circular ossicles, the technique is applicable only if the disks are truly parallel to bedding; if they are not, the undeformed profile in the bedding plane is elliptical (Engelder & Engelder 1977, Spratt 1987). [8]In both these cases, the measured ossicle shape and orientation are not those of the strain ellipse, but rather those of the combined effect of the initial form and the strain ellipse. [9]A related problem was pointed out by Ramsay (1967), who demonstrated that a cross-section perpendicular to the axis of a deformed cylinder generally does not represent the strain ellipse, as it usually is derived from an oblique, elliptical cut through the undeformed cylinder.

[10]Spratt (1987), in a detailed analysis of deformation mechanisms within crinoidal limestones of the Canadian Rockies, acknowledged and addressed these problems. [11]First, she documented that the ossicles were initially circular by measuring the shapes of relatively undeformed samples. [12]Second, by microscopically determining the orientation of the c-axis of each crinoid stem (which forms a single calcite crystal), she was able to calculate and remove the effects of oblique cuts through ossicles, and thus specify both the original ellipticity of the cut and the true strain ellipse. [13]Since this is applicable to ossicles and thin sections of any orientation, her technique allows the three-dimensional strain to be calculated, as long as the undeformed cross-sectional shapes are known.

[14]In this contribution, two new methods are presented for determining the three-dimensional strain from crinoid ossicles. [15]Like the technique of Spratt (1987), both are applicable to rocks, typically crinoidal grainstones, in which ossicles are randomly oriented. [16]Furthermore, both methods make use of the two-dimensional shapes created by thin sections cutting the three-dimensional cylindrical ossicles; these shapes can be evaluated by the standard Rf/ (e.g., Ramsay 1967, Dunnet 1969, Lisle 1977) and angular shear strain (Breddin 1956a, Ramsay 1967) techniques. [17]The three-dimensional strain is calculated from measurements of two-dimensional strain on three mutually perpendicular sections (Ramsay 1967, Siddans 1980) or three or more non-perpendicular sections (Owens 1984). [18]Two advantages of these new methods over that developed by Spratt (1987) are that the c-axis orientations need not be determined, and knowledge of the original shape of the ossicles is not required.

Appendix E-2

Pakistani Geology RA Introductions used in the study

PAK-01: A-Type granites of Warsak, Khyber Agency, N. Pakistan: Rift-related acid magmatism in the Indian Plate

[1]The Warsak granites are amongst the earliest recognised peralkaline granites in N. Pakistan (Coulson, 1936). [2]Ahmad et al., (1969) mapped these granites in detail, while Kempe (1973) presented a comprehensive petrography and whole-rock chemistry (mainly the major elements). [3]Kempe & Jan (1970, 1980) correlated these granites with peralkaline granites of Shewa-Shabazgarhi, Tarbela, and Ambela, and suggested that they formed an integral part of a Tertiary alkaline province located in and around the Peshawar plain.

[4]In this paper we use trace-element geochemistry to show that the Warsak granites, irrespective of their peralkaline or peraluminous character, are a typical example of A-type granites (cf: Loislle & Wones, 1979; Collins et al., 1982; Whalen et al., 1987). [5]Such granites are considered to represent final plutonic event in rift-related anorogenic magmatism of shield areas (Whalen et al., 1987). [6]On the basis of a previously established correlation with the granites of Ambela and Shewa-Shabazgarhi (Kempe & Jan, 1970, 1980; Kempe, 1980; Jan & Karim, 1990), we suggest a Palaeozoic age for the Warsak granites and consider them to be a consequence of Late Palaeozoic fragmentation of the Gondwanaland.

PAK-02: Heavy mineral analysis of the molasse sediments, Trans-indus Ranges, Kohat, Pakistan

[1]Heavy minerals are commonly used for the identification of source areas and establishing stratigraphic correlations among different formations. [2]This technique was first applied to the molasse sediments in the Himalayan foreland basin by Krynine (1937). [3]Subsequent studies, however, ignored the heavy minerals, and mainly concentrated on sedimentology (Behrensmeyer & Tauxe, 1982; Nio & Hussain, 1984), biostratigraphy (Raza, 1983), magnetostratigraphy (Khan, 1984; Johnson et al., 1985), and petrography (Abid et al., 1983; Abbasi & Friend, 1989). [4]With the availability of an adequate data on mineral chemistry from the Himalayan orogenic belt in N. Pakistan (Jan, 1977; Jan & Howie, 1980, 1981, 1982; Bard, 1983; Khan, 1988; Jan, 1988; Jan et al., 1989; Khan et al., 1989; Treloar et al., 1989a, 1989b; Williams, 1989; Jan & Windley, 1990), it is now possible to compare the heavy minerals in the molasse sediments from the foreland basin to exactly locate the source terrain for each stratigraphic level. [5]In this paper we present data on heavy minerals from the molasse sediments exposed in the Kohat foreland basin (Fig.1), in terms of their modal abundance and composition, and attempt to interpret the nature of their source terrain. [6]The molasse sediments in the Kohat foreland-basin are over 6 km thick and comprise two coarsening upward sequences (Fig.2); a basal Rawalpindi Group consists of the Murree and Kamlial formations, while the Siwalik Group comprises the Chinji, Shakardarra (stratigraphically equivalent to the Nagri Formation in the Potwar area) and the Indus conglomerate Formations (stratigraphically equivalent to the Dhok Pathan Formation in the Potwar area). [7]Sandstone constitutes a major proportion (about 70%) of the molasse sediments, with subordinate siltstone and conglomerates in the study area. [8]For the purpose of heavy mineral separation and their chemical (microprobe) analysis, ten sandstone samples were selected from the Hukni section around Shakardarra area (Fig.1), where a stratigraphically continuous molasse succession is well exposed.

PAK-03: Shallow marine sediments of the patala formation of paleocene age, Kohat area, Pakistan

[1]The Patala Formation is the youngest Paleocene formation exposed in Kohat- Potwar Plateau, Hazara and Salt Range (Shah, 1977). [2]The present study is confined only to the exposures in the Kohat area (Figs.1 and 2). [3]In this area, the formation overlies the Lockhart limestone (more correctly Lockhart Formation). [4]The upper contact of the Patala Formation is not exposed in the Kohat Pass but at some localities in the Kohat area such as at Panoba it is underlain by the Panoba Formation. [5]In Kohat Pass the area is structurally disturbed and the sequence is locally overturned (Ghauri, pers. comm., 1989).

[6]Only previous sedimentological study on the Patala Formation is by Rashid et al., (1988) but they misunderstood the overturned sequence as normal (Ghauri & Obaid-ur-Rehman, pers. comm. 1989). [7]General structural and stratigraphic studies in the Kohat Pass have been done by Ghauri et al., (1983).

[8]Meissner et al., (1974) described the Patala Formation from various localities within the Kohat Quadrangle. [9]The present study deals with the lithofacies and paleoenvironments of the Patala Formation, based on two relatively better exposed and easily accessible sections; one at Kohat Pass in Khyber Agency and the other at Samana Fort in Orakzai Agency (Figs.1 and 2). [10]No coal association is present at these localities in these strata.

PAK-04: Structures in the hangingwall of the main boundary thrust: post- folding thrust and normal faults from the Kotal-pass area, Kohat Range, N. Pakistan

[1]The Main Boundary Thrust (MBT) is a regional lineament in the external zone of the Himalayan thrust-fold belt in N. Pakistan, which brings the Mesozoic- Cenozoic shelf sediments of the Margala-Kalachitta-Kohat Hill ranges to lie tectonically over a pile of molasse sediments deposited in the foreland basin. [2]Disruption along the MBT zone started probably around early Miocene times as suggested by the involvement of the late Oligocene-early Miocene Murree Formation in deformation (Burbank, 1983). [3]A diverse assemblage of structures is reported associated with this major fault structure, including thrust faults in imbricate and duplex systems, backthrusts and divergent fold structures.

[4]These structures are spread over an approximately 20km wide zone in the Kohat range, where they form a major pop-up structure (Ghauri et al., in prep.).

[5]Earlier accounts of the MBT and its associated structures are given by Cotter (1933). [6]Various segments of the MBT zone have been subsequently mapped in relatively greater details, resulting in the recognition of a large number of fold and thrust structures associated with it (Gardezi, 1974; Gardezi et al., 1976; Ghauri et al., 1983; Akhtar et al., 1984; Izatt, 1990).

[7]Recently, we have started a programme of reinvestigation of the structures in the hangingwall of the MBT, concentrating in the part of the Kohat range in the Dara Adam Khel area (K.A. Turi, work in progress). [8]In the process we have carried out detailed analyses of the thrust and fold structures which were previously outlined by Gardezi et al., (1976) and Ghauri et al., (1983). [9]A detailed account of them will be published subsequently. [10]In this paper, we present data on a set of out-of-the syncline thrust and normal fault structures from the Kotal-Pass area of the Kohat range (Fig.1), which have not been previously recognized, and which, in our opinion, represent the youngest phase of the tectonic activity associated with the MBT.

PAK-05: The Tora Tigga Complex, Southern Dir, NW Pakistan: An example of mafic-ultramafic rocks in the bottom of an island arc

[1]Northern Pakistan is characterized by the presence of two suture zones, the Main Karakoram Thrust (MKT) in the north and the Main Mantle Thrust (MMT) in the south. [2]These are the westerly bifurcation of the Indus Zangbo suture and enclose ~ 36,000 km^2 area of the Cretaceous Kohistan island arc. [3]North of MKT lies the Karakoram plate and south of MMT the Indo-Pakistan plate. [4]The Kohistan arc is tilted so that a complete cross section is exposed. [5]Along a N to S traverse across the arc, the following major lithologies, each stretching for several hundred kilometers, are observed: Middle Cretaceous Yasin sediments; Late Jurassic-Cretaceous Chalt volcanics; Creto-Tertiary calc- alkaline granitic belt; Early to Middle Cretaceous Chilas complex; and southern amphibolite belt (for further detailes, see Jan, 1977; Tahirkheli & Jan, 1979; Tahirkheli et al., 1979; Butt et al., 1980; Andrews-Speed & Brookfield, 1982; Coward et al., 1982, 1986; Bard, 1983; Petterson & Windley, 1986).

[6]The Chilas complex comprises norites, with subordinate anorthosites, quartz- hypersthene diorites, gabbros, troctolites, pyroxenites, peridotites and dunites. [7]These rocks may partly represent cumulates in the magma chamber of the arc and have re- equilibrated under pyroxene granulite facies conditions, followed by amphibolite facies retrogression during ascent (Bard, 1983; Jan et al., 1984). [8]The southern amphibolite belt lies just north of the MMT and contains homogeneous and banded amphibolites derived from island arc volcanic and plutonic rocks that may be the metamorphic equivalent of the Dras volcanics found to the east of Nanga Parbat in Ladakh (Honegger et al., 1982). [9]The belt also contains a variety of other lithologies such as metamorphosed gabbros/ norites, troctolites, ultramafites (some of which resemble those of the Chilas complex), granitic rocks, and minor calcareous and siliceous metasediments.

[10]The Tora Tigga complex (3449'N, 7144'E) is an example of the plutonic masses found in the amphibolite belt. [11]It is located immediately north of the MMT and is characterized by an abundance of hornblendites. [12]Based on a study of 170 thin sections and 23 analyses (major and trace elements by atomic absorption and XRF), a summarised petrographic and geochemical account of the complex is presented in this paper. [13]Additional details can be found in Banaras & Ghani (1982), Jan et al., (1983) and Tahirkheli (1983).

PAK-06: Petrology of the Shewa-Shabazgarhi Complex, Mardan, North Pakistan

[1]The Shewa-Shabazgarhi complex is an isolated triangular outcrop (Fig. 1) consisting of basic and acidic meta-igneous rocks occurring ~60km south of MMT (Main Mantle Thrust) in the Indo-Pak plate and emplaced into a metasedimentary sequence known as the Sawabi-Chamla group of possible Precambrian age. [2]The complex is located about 12km northeast of Mardan (longitude 7210'- 7220'E, latitude 3710' - 3430'N) and has been frequently investigated by workers since Coulson (1936) who described the petrography and chemistry of some of the rocks for the first time. [3]He described these rocks as porphyrites of Mesozoic age and correlated these with the soda granite at Warsak. [4]Martin et al., (1962) called these rocks as albite porphyries and pointed out cataclasization in certain types. [5]Several other workers (Siddiqui, 1965; Chaudhry & Shakoor, 1968; Kempe & Jan, 1970; 1980; Kempe, 1973; 1983; Ahmed & Ahmed, 1974; Chaudhry et al., 1976; Bakhtiar & Waleed, 1980) have investigated these rocks and correlated with various complexes of the Peshawar alkaline igneous province, in particular with Koga alkaline complex (cf. Fig. 1). [6]These workers have assigned a probable Early Tertiary to Late Cretaceous age to the rocks of the Shewa-Shabazgarhi complex.

[7]The different rock types described by previous workers and also under present investigation are: (a) metagabbro, metadolerite [associated with local quartz monzonite] and basic dykes comprising the basic suite, and (b) microporphyry, riebeckite gneiss, aegirine-riebeckite porphyry and the acidic dykes comprising the acidic suite. [8]A small outcrop of basaltic breccia reported by Ahmad (1986) north-west of Asota (Fig. 2) may also be included in the basic group. [9]The country rocks hosting the igneous lithology are the metasediments of the Sawabi-Chamla group comprising mainly of phyllitic shale, quartzite and schist (Fig. 2; see also Noor Jehan, 1985; Ahmad, 1986).

[10]The present study was carried out to map and perform further petrographic and geochemical study of the complex in order to determine magmatic affinities and tectonic environment and elucidate the metamorphic and igneous crystallization histories of the various rock types in the Shewa-Shabazgarhi complex. [11]Samples were prepared and analyzed for major and trace elements by wet chemical and X-Ray Fluorescence techniques, using U.S.G.S. standards, in the National Centre of Excellence in Geology, University of Peshawar. For details see Ahmad (1986).

PAK-07: Sodic pyroxenes and amphiboles from Koga syenites of Ambela Granitic Complex, N.W.F.P., Pakistan

[1]Carbonatites are typically surrounded by metasomatic aureoles, which develop as a result of metasomatism of country rocks by the carbonatite fluids emanating during the emplacement. [2]Although many authors (Mckie, 1966; Currie & Ferguson, 1971; Le Bas, 1977; Vartiainen, 1980; Viladkar, 1980; Woolley, 1982; Rubie & Gunter, 1983; Mian & Le Bas, 1986,1987,1988) have made extensive studies of fenitization by carbonatites but the process is still not well understood. [3]This is partly because of the uncertainties of the nature of the fenitizing fluids, but also because of the variation in mineralogical composition, texture, chemical reactivity, the state of oxidation and permeability of the country rocks. [4]At Koga in NW Pakistan carbonatites and/or ijolites have intruded and fenitized the syenitic rocks.

[5]To understand the process of fenitization in general and behaviour of Na- pyroxene and Na-amphibole (pyriboles) in particular, samples are collected from different syenitic rocks of Koga. [6]This paper presents the variation in the chemistry of magmatic and fenitic pyrobole as a result of fenetic fluids emanating from the carbonatite. [7]The revers changes in chemistry, in contrast to the magmatic pyroboles, correlate with the grade of fenitization by the carbonatites having different Na/K ratios.

PAK-08: Large scale vertical aggradation of sandstones in the kamlial formation of the Kohat Basin, Pakistan

[1]The early detritus shed by the Himalayan orogenic belt was deposited in the Kohat-Potwar foreland basin (Fig. 1) as a coarsening upward sequence, known as the Rawalpindi Group. [2]The Rawalpindi Group is comprised of the Murree Formation lying unconformably over the Eocene limestone, and Kamlial Formation which has a transitional contact with the overlying Siwalik Group (Shah, 1977)(Fig. 2). [3]These sediments are characterized by a succession of transient depocentre which migrated outwards from the orogenic belts as the deformation rippled southwards (Raynolds & Johnson, 1985). [4]The molasse sediments comprising the Rawalpindi and Siwalik Groups in the Kohat-Potwar fold-thrust belt during the last two decades have been the focus of multidisciplinary studies including magnetostratigraphy (Opdyke et al., 1979; Johnson et al., 1979, Jounson et al., 1982, 1985; Burbank, 1983, Khan, 1983, 1984; Tauxe & Badgely, 1988), biostratigraphy (Pilbeam, 1982; Raza, 1983; Raza et al., 1984), lithostratigraphy (Fatmi, 1973; Shah, 1977) and sedimentology (Visser & Johnson, 1978; Behrensmeyer & Tauxe, 1982). [5]Most of these studies were, however, concentrated on the rocks of the Siwalik Group, whereas little informations are available regarding the sediments of the Rawalpindi Group. [6]The Kamlial Formation in the Kohat-Potwar fold-thrust belt is comprised of greenish-grey sandstone (73 %) with subordinate maroon siltstone (20 %) and minor intraformational conglomerate (7%) (Fig. 3). [7]The total measured thickness of the Kamlial Formation in the Shakardarra area, southeastern Kohat (Fig. 3), is 580 metres, but in the south thins out to about 50 metres in the Surghar Range (Meissner et al., 1974).

[8]The Kamlial Formation contains comparatively higher proportion of siltstone in its lower and middle part than in its upper part. [9]Sandstone sequences in its upper part are up to 100 metre thick, whereas in the lower part, the sandstones are up to 30 metres thick (Fig. 3). [10]Bioturbation is common in the upper parts of the sand units and destroys depositional structures. [11]Spheroidal weathering is also common and gives a rubbly, massive appearance to the sandstones. [12]The Kamlial Formation despite its regional distribution has been devoid of any detailed sedimentological studies. [13]The only studies in progress at present are those of Hutt (in prep) in the southern Potwar area. [14]This sudy is first of its kind and will deal mainly with the sandstone body geometry and the probable paleoriver system which deposited these sediments. [15] An area around Shakardarra village in southeastern Kohat (Fig. 1) was selected and detailed studies were carried out mainly along the stream sections.

PAK-09: Structure and stratigraphy of the Northern Gandghar Range, Hazara, Pakistan

[1]The NE-SW trending Gandghar Range is located in the Hazara Division, some 40km northwest of Islamabad. [2]It forms a partial barrier between the Pliestocene Haripur and Peshawar basins (Fig. 1). [3]North of the Gandghar Range, in the Hazara Ranges, the Tanawal Formation is intruded by the Cambrian Mansehra granite. [4]The Gandghar Range is bound in the east by the Khanpur Hills and in the southeast by the Margala Hills.

[5]The Gandghar Range strata are transitional between the high grade metamorphic and plutonic rocks to the north and unmetamorphosed foreland basin strata to the south. [6]It is structurally continuous with the northern block of the Attock-Cherat Range (Yeats and Hussain, 1987) and records the transition between the Himalayan rocks and foreland basin strata.

[7]Hylland et al., (1988) have described the stratigraphic and structural relationships of the rocks that underlie the southern Gandghar Range. [8]This paper is an attempt to extend the same relationships to the rocks of the northern Gandghar Range.

PREVIOUS WORK: [9]All of the earlier literature on Hazara describe the geology of the Gandghar Range in a regional context (e.g., Wynne, 1872; Wynne, 1879 and Middlemiss, 1896). [10]They mentioned the infra-Triassic limestone and Paleozoic Slate Series which was correlat ed with the pelitic rocks of Attock (Cotter, 1933). [11]The limestone units have also been considered to be the part of the Precambrian Hazara Slates (Ali, 1962), whereas Tahirkheli (1971) mapped all of the rocks comprising the Gandghar Range to be of Paleozoic age. [12]The structural relationships of the rocks of the northern Gandghar Range were explained by the existence of large folds and a thrust fault (Calkins et al., 1975).

PAK-10: Petrology and the grain size characters ofthe pab sandstone of parts of the Loralai and Khuzdar Districts of Baluchistan

[1]The term Pab Sandstone was introduced by Vredenburg (1908), the name drived from Pab Range in Kirther Province. [2]Williams (1959) designated the Somalji trail west of Wirahab Nai across the Pab Range as type locality.

[3]The formation consists of quartzose sandstone of white, creme and reddish brown colours which weathers yellowish brown, fine to coarse grained, moderately to well sorted, subrounded to well rounded, thick bedded and commonly cross stratified. [4]Some marl and argilaceous and siliceous limestone is also intercalated with the sandstone. [5]Shale is very subordinate.

[6]The formation is widely developed in the studied areas (Fig. 1) which lies within the Axial Belt, although, it is very highly developed in the Sulaiman and Kirther Provinces. [7]It conformably overlies the Fort Monro Formation in the Sulaiman and Kirther Provinces and overlain by the Khadre Formation of Ranikot Group, however, in the studied areas stratigraphic position of the Pab Sandstone is as under: ....

[8]The present paper is intended to describe the petrology and grain size parameters of the Pab Sandstone and an attempt has been made to interpret the provenance and depositional environments based on petrology and grain size parameters. [9]Samples for the analysis were taken from Shehan Rud, (Fig. 1), about 4 miles northeast of Murgha Kibzai 63 miles northeast of Loralai on Loralai-MusaKhel road, from Siazgi 38 miles northwest of Loralai, from Gunga Kili nearly 7 miles west of Khuzdar and Siman 6 miles west of Pir Umar and 25 miles south of Khuzdar.

PAK-11: LITHOFACIES ASSOCIATIONS AND PALEOCURRENT PATTERNS IN THE NAGRI FORMATION OF THE SIWALIK GROUP IN KACH-ZARGHUN AREA OF NORTHEAST BALUCHISTAN

[1]The Stratigraphic Committee of Pakistan (Fatmi, 1974) subdivided the Siwalik Group into Chingi, Nagri, Dhok Pathan and Soan Formations among which the lowermost Chingi Formation is not recognised in Baluchistan. [2]Here the Nagri Formation overlies unconformably various older formations ranging in age from Triassic to Eocene with angular discordance, whilst, its upper contact with the Dhok Pathan Formation is transitional. [3]The Nagri Formation consists mostly of sandstones with very minor amount of claystone and siltstone partings. [4]The formation has been interpreted (Kassi, 1987) as a deposit of braided channel system which have derived its detritus from the nearby mountain ranges.

[5]The present paper is based on the study of the lithofacies associations of the Nagri Formation in two sections on Quetta-Ziarat road near Kach Levy Post (Fig. 1) and paleocurrent patterns in 25 localities around Zarghun, Kach, Gogai, and Rud Malazai. [6]New proposals are made and amendments proposed in earlier work (Kassi, 1987) regarding lithofacies associations and paleocurrent patterns and the study area extends to Ahmadun, Gogai, Tangai, Rud Malazai and various other localities around Zarghun.

PREVIOUS WORK: [7]In Baluchistan the stratigraphic study of the Siwalik Group was initiated by the Hunting Survey Corporation (1961) which was subsequently standardised by the Stratigraphic Committee of Pakistan (Fatmi, 1974). [8]Kazmi & Raza (1970) also described the local stratigraphy of the Siwaliks in Quetta region and proposed local names of the formations. [9]Kassi (1987) and Kassi et al., (1987) described the preliminary sedimentology and petrology of the Siwaliks of Kach and Zarghun areas and made comments on their paleoenvironments and provenance. [10]Kassi (1989) also commented on the grain size parameters of the conglomerate units of the Soan Formation.

PAK-12: STRATIGRAPHIC CONTROL FOR THE AGE OF PESHAWAR-PLAIN MAGMATISM, NORTHERN PAKISTAN

[1]A restricted part of the internal zone of the Indian plate comprising Peshawar plain and lower Swat foothills is characterised by an assemblage of plutonic igneous rocks which define an alkaline igneous province in this region (Kempe & Jan, 1970, 1980; Kempe, 1973, 1983, 1986; Le Bas et al., 1987; Jan & Karim, 1990). [2]The various igneous complexes of the province include Shilman, Warsak, Tarbela, Shewa-Shahbazgharhi, Ambela, Koga, Malakand and Silai Pattai, and comprise a diverse assemblage of rocks including peralkaline to alkaline granites, syenites, feldspathoidal syenites, carbonatites, ijolites, and albitites. [3]A phase of tholeiitic basic magma is closely associated, both in space and time, with the alkaline magmatic activity in the Peshawar plain alkaline province. [4]This basic magmatism occurs in both plutonic and hypabyssal bodies in the form of intrusive sheets, dykes and sills (e.g., Warsak, Tarbela). [5]Hitherto, no extrusive equivalents of alkaline or acidic composition have been reported, though Kempe (1978) described some of the basic rocks at Warsak to be metamorphosed tuffs and lava flows.

[6]One of us (SRK) has recently carried out detailed mapping in parts of the Swabi, Mardan and Buner districts, at the northeastern edge of the Peshawar plain (Fig. 1). [7]We report closely spaced, both in space and time, bimodal volcanism from this part of the Peshawar plain. [8]Data are presented for stratigraphic control on the age and nature of emplacement for these igneous rocks. [9]We consider that the acid volcanics reported here are extrusive equivalents of the subvolcanic Shewa-Shahbazgarhi and Warsak microporphyries (porphyritic microgranites of Kempe, 1973), whereas the basaltic volcanics are correlative with the Panjal volcanics of Kashmir and Kaghan valleys and the extensive suite of tholeiitic basic dykes spread over most parts of the internal zone of the Indian plate (Attock-Cherat-Khyber ranges, Peshawar plain, Swat, Hazara and Kashmir areas). [10]The occurrence of these volcanics at specific stratigraphic positions in the Late Paleozoic succession of the Peshawar plain and lower Swat has important implications for the age and nature of the magmatism in the alkaline province.

PAK-13: MYRMEKITE IN THE AMBELA GRANITIC COMPLEX, N. PAKISTAN: A PRODUCT OF DEFORMATION AND REPLACEMENT IN THE FELDSPAR

[1]A corroded feldspar with vermicules within an orthoclase grain was first described by Michel-Levy in 1875, and later on such intergrowths were named as myrmekite by Sederholm (1899). [2]Details of the early work on myrmekite were summarised in Sederholm (1916) and Drescher-Kaden (1948). [3] Phillips (1974, 1980) reviewed the various hypotheses for the genesis of myrmekite and presented a modern supplement to the work of Sederholm (1916) and Drescher- Kaden (1948).

[4]The role of deformation in the replacement of K-feldspar by myrmekite, particularly in acidic plutonic rocks, was first recognised by Futherer (1894). [5]Several later workers (e.g., Eskola, 1914; Spencer, 1945; Sarma and Raja, 1959; Shelly, 1964; Bhattacharyya, 1971; Phillips and Carr, 1973) pointed out the significance of deformation in the origin of myrmekite. [6]Indeed, deformation is considered to be an effective means of driving replacement reactions (Wintsch and Knipe, 1983; Tullis, 1983; Vernon et al., 1983; Hibbard, 1987; La Tour and Barnett, 1987). [7]Another mechanism which is considered to be responsible for the formation of some of the naturally occurring myrmekites is solid-state diffusion and exsolution (Schwantke, 1909; Phillips, 1974), which is considered to be more effective during deformation (White, 1975; Simpson, 1985) than under normal conditions.

[8]In this paper we present examples of myrmekites occurring in strained K- feldspar porphyroclasts in sheared granites from the Ambela Granitic Complex (AGC), and explain their growth in terms of a collective role of solid-state diffusion and reaction replacement under directed stresses.

PAK-14: PETROGRAPHY AND GEOCHEMISTRY OF THE INCLUSIONS FROM THE AMBELA GRANITIC COMPLEX, N. PAKISTAN

[1]The Ambela Granitic Complex (AGC), which is one of the principal constituents of the Peshawar Plain Alkaline Igneous Province (Kempe and Jan, 1970, 1980; Kempe, 1973,1983; Butt et al., 1980; Le Bas et al., 1987) has been a subject of several studies over the last three decades. [2]Detailed petrographic accounts together with analytical data on major and trace element geochemistry for the principal lithologies of the complex (granites and syenites) have been included in several papers (Siddiqui, 1965; Siddiqui et al., 1968; Chaudhry et al., 1981; Rafiq et al., 1984; Rafiq and Jan, 1988). [3]An important component of the complex so far undescribed, however, is the inclusions of intermediate to felsic

composition which are contained in both the granites and syenites. [4]In this paper, we present petrographic data and whole-rock geochemistry for a representative set of samples from these inclusions. [5]An attempt is made to decipher their origin by comparing their trace element composition with their host rocks from the AGC, and country rocks in the surroundings.

PAK-15: STRATIGRAPHY OF THE DUNGAN GROUP IN KACH-ZIARAT AREA, N.E. BALOCHISTAN

[1]Thick bedded to massive foraminiferal limestone, interbedded with subordinate shale, was first noted in northeastern Balochistan and described by Griesbach (1881) as "Alveolina Limestone". [2]However, credit must go to Oldham (1890) for correctly reading the stratigraphic position of these rocks and naming these as "Dungan Limestone" after the Dungan hill, 50 km southeast of Harnai, where this limestone forms a large anticline. [3]Oldham's "Dungan Limestone" comprised all the strata lying between two distinct formations' the overlying Ghazij Shale (Eocene) and the underlying Parh Formation (Cretaceous). [4] He described the Dungan Limestone as "compact, bedded, blue or dark grey limestones, generally unfossiliferous in lower portion but upper beds contain numerous fossil ..."

[5]Later Oldham (1892) noted that the lower part of the Dungan Limestone abruptly changes from calcareous to argillaceous facies in the Marri area, where the limestone is underlain by 61 m of sandstone and 305 m of shale. [6]According to Oldham these shales yielded Nummulites, with Cretaceous echinoids, Crioceras, Baculites, and ammonites. [7]Oldham, therefore, correctly assigned a Late Cretaceous to Eocene age to the Dungan Limestone.

[8]The "Dungan Limestone" of Oldham extends over a vast area in northeastern Balochistan and may be identified from near Khuzdar northward to the Bolan Pass and Quetta area, then eastward through the Marri-Bugti and Loralai region all the way upto the Sulaiman Range, extending as far northeast as the Gomal River in Dera Ismail Khan. [9]Since Oldham, many geologists have studied the Dungan Limestone, notably Davies (1941), Eames (1952), Kazmi (1955, 1961), Williams (1959) and Hunting Survey Corporation (HSC) (1960). [10]Oldham (1890) and Davies (1940) proposed Dungan Hill as the type area for the Dungan Limestone. [11]Williams (1959) proposed the Mehrab Tangi Section near Harnai as the type area. [12]Based on the study of stratigraphy of the Dungan Limestone in Ziarat area as well as in other areas, the author herein proposes that the Anagan Gal Section, at Ziarat, should also be considered as an important area for the Dungan Limestone. [13]The details and discussion that follow seek to justify this suggestion.

[14]The author supports the HSC (1960) in naming the Dungan Limestone as the "Dungan Group". [15]Apart from its interesting stratigraphic features, this stratigraphic unit is of considerable interest because it is a potential host rock for hydrocarbons as it contains oil at Khatan (Harnai Valley) and gas at Pirkoh and Sui. [16]East of Quetta, there are many structures in which the Dungan Limestone may be containing commercial quantities of oil.

PAK-16: CLAY MINERALOGY OF THE QUATERNARY LAKE DEPOSITS OF PESHAWAR BASIN, AT JEHANGIRA, DISTRICT MARDAN, N.W.F.P., PAKISTAN

[1]Post-Siwalik Quaternary sediments of the Peshawar valley have attracted the attention of various geologists (Abbott, 1849; Allen, 1964; Burbank, 1982; Haneef et al., 1986) and consist of alluvial fans, loess, catastrophic flood deposits and lacustrine strata. [2]The lacustrine strata are exposed at various localities. [3] Their outcrops near Jalala (80 km north of Peshawar along Peshawar-Swat highway) and Jehangira (about 3 km north of Jehangira town, along north flank of Kabul River), (Fig.1), are very conspicuous and eye catching. [4]More than 15 m thick sequence of gray to light gray, horizontal clay beds is exposed. [5]Thickness of individual strata varies from 19cm to 60cm. [6] Base of this clay sequence is not exposed and drill holes are not present in this area. [7]The individual strata show good stratification and some plant remains are also present. [8]These clay strata are overlain by sand deposits of modern Indus and Kabul Rivers. [9]It is very likely that the clay beds were deposited in a lake which covered most of the Peshawar valley. [10]The lake itself might have formed due to catastrophic flooding of the Indus River which, as reported by Burbank (1983), are a frequent feature (over geologic time) in Peshawar valley. [11]The extent of a major lake formed by the damming of Indus River is yet to be studied. [12]Present studies are confined to the identification of the clay minerals present in the bedded clay deposits exposed near Jehangira. [13]For this purpose, ten samples form the Jehangira lake deposits were studied. [14]Five samples from the bright red claystone unit of the Chinji Formation (Lower Siwalik Group) from Jalalpur, Eastern Salt Range, were studied for comparison of the provenance.

PAK-17: ISLAND ARC SIGNATURES FROM THE WAZIRISTAN IGNEOUS COMPLEX, N.W.F.P., PAKISTAN

[1]The suture zone that dissociates the Indo-Pakistan plate from the Eurasian block and the Gondwanic microcontinents (e.g., the Afghanistan and Iran blocks; cf. Shah, 1984), is marked by a number of mafic and ultramafic complexes. [2]Some of these have been considered as fragments of oceanic crust/ophiolites (e.g., Gansser, 1979), while others have been associated with Island arc(s) (e.g., Jan et al., 1984). [3]Among these mafic-ultramafic complexes no less than six occur in Pakistan. [4]With an area of 500sq.km., the Waziristan igneous complex stands as the third largest of these complexes, after Bela and Zhob (cf. Baker and Jackson, 1964; Kazmi and Rana, 1982). [5]The Waziristan igneous complex is located in the North and South Waziristan agencies of the tribal belt of Pakistan. [6]Some preliminary investigations of the area have been conducted in the past (Khan et al., 1982; Badshah, 1985; Jan et al., 1983, 1985). [7]The complex is associated with Jurassic-Cretaceous and Early Tertiary stratigraphic sequences and is locally covered by Quaternary deposits. [8]It occurs in thrust slices overriding the Mesozoic sequence of the Indo-Pakistan plate, and is unconformably overlain by the Eocene strata. [9]Thus, it can be inferred that the Waziristan igneous complex was allochthonously emplaced in the Palaeocene to early Eocene. [10]This time of emplacement is similar to that of Bela (Ahmed and Abbas, 1979; Allemann, 1979) and Zhob (DeJong and Subhani, 1979) ultramafic complexes, thus coinciding with the event of the closure of the Neo-Tethys (also see Hamidullah and Onstat, in press).

[11]Complexity of structure in the area depicts intense tectonic activity (Fig. 1). [12] No stratigraphic sequence is discernible in the igneous complex and its configuration is mostly chaotic, due to imbricate thrusting and folding; nevertheless, the different rock types that have been recognised by the previous workers are: ultramafic masses, mafic to intermediate intrusives and basic to acidic extrusives. [13]The ultramafic rocks consist of serpentinized peridotites, dunites, and pyroxenites. [14]The intrusives comprise gabbros, diabase and diorites, whereas the volcanics consist of pillow basalts, andesites,

dacites, rhyodacites, tuffs and agglomerates. [15]Abundant copper mineralization has also been reported from the complex (Badshah, 1985).

[16]So far, the entire Waziristan igneous complex has been labelled as an ophiolite complex (Asrarullah et al., 1979; Khan et al., 1982; Shah, 1984; Badshah, 1985; Jan et al., 1985), neglecting the significance of dacites, andesites and associated tuffs, agglomerates and copper deposits. [17]Such an association is, however, not very typical of oceanic crustal environments. [18]Rather, it is indicative of supra-Benioff zone igneous activity (Hughes, 1982).

[19]The main object of our present work was to study primary mineral chemistry of Waziristan igneous complex, leading ultimately to petrogenetic interpretation. [20]Samples from peridotite, gabbro, diabase and some volcanics were collected for this purpose. [21]Mineral compositions were determined with computer automated 2-spectrometer JCXA-733 electron microprobe, using wavelength dispersive system Data were reduced on-line using ZAF quantitative analysis programme and reference to natural and synthetic standards.

PAK-18: PETROLOGY OF KAKUL PHOSPHORITES, DISTRICT ABBOTTABAD, N.W.F.P., PAKISTAN

[1]Palaeozoic phosphate occurrences at Kakul-Mirpur area of Hazara division were first discovered by Latif (1970). [2]A number of other deposits were later discovered in the same litho-tectonic setting in and around Abbottabad city. [3]Significant contributions to the geology of Hazara have been made by a number of workers (Vercheres, 1966; Weagen and Wyne, 1962; Davies and Gardezi, 1965). [4]Calkins and Martin (1968) were the first to work on the mineral resources of the Garhi Habibullah and Kakul areas of the Hazara division. [5]Detailed work on the geology and phosphate resources of district Abbottabad was carried out by Latif (1974), Bhatti and Hasan (1972), Ghaznavi and Karim (1978), Ashraf and Malik (1983).

[6]The Kakul-Mirpur, Lagarban and Dalola areas occur within the east longitudes 7316' and 7330' and north latitude, 3412' and 3415'. [7]The southern part of the area is accessible via Kakul which is linked with Abbottabad city by 5km metalled road, while the northern part of the area is 7km from Abbottabad on the Mansehra road.[8]Of the known deposits around Abbottabad, only those at Kakul are being commercially exploited.

[9]The phosphorite deposits of Kakul-Mirpur area occur in the Kakul Formation of Abbottabad Group (Tahirkheli, 1971; Bhatti, 1972). [10]Total reserves have been estimated as 1.08 million metric tonnes. [11]The main phosphate horizon, having an average thickness of 4.5 metres, is truncated by faults on both sides (Latif, 1974). [12]Tight folding and subsequent faulting are the normal features of the area which have adversely affected the deposits (Hasan and Ghaznavi, 1980).

[13]Recent advances in phosphate geology research have made it easier to understand phosphorite system more comprehensively. [14]A well-defined terminology has been introduced by Riggs (1979), Prevot (1981), Cook and Shergold (1986), and Slansky (1986) to describe any phosphorite system in terms of its petrography, mineralogy and genesis, and deciphering an ancient sedimentary environment which can act as a tool in discovering new phosphorite deposits both onshore and offshore.

[15]In the present paper, an attempt has been made to study some Kakul phosphorite samples and their associated rocks for their petrological characters.

PAK-19: SEDIMENTOLOGY OF THE GHAZIJ FORMATION, KACH AREA, BALUCHISTAN

[1]The Ghazij Formation has been attracting attention of the geologists because of its natural wealth of coal and alabaster. [2]Coal has been mined from the Ghazij Formation in various areas of Baluchistan like Sor Range, Degari, Duki, Mach and Sharigh. [3]The formation comprises dominantly of shales and subordinate sandstones and conglomerates, with alabaster and coal seams. [4]The shales are of pale greenish-grey, brown, reddish-grey, olive grey, maroon and purple colour, calcareous, hard and flaky. [5]Sandstones are dark grey, greenish and brownish-grey, medium to coarse grained, poorly sorted and subangular to subrounded. [6]Conglomerate consists of poorly sorted and well rounded fragments of granules to cobbles range. [7]The formation is 590 m thick at type section in Spintangi. [8]It conformably overlies Dungan Formation, Laki Formation and Rani Kot Group of Palaeocene age in different areas and underlies the Kirther Formation of Upper Eocene. [9]Age of the Ghazij Formation is Early Eocene based on fossil content.

PREVIOUS WORK: [10]The formation was initially mapped by Oldham (1890), Williams (1959), and Hunting Survey Corporation (1961) and was subdivided into the Baska Shales (Alabaster Member) and Marap Conglomerate Members. [11]Megafauna and stratigraphy of the formation has been dealt with in detail (Kazmi, 1962; Iqbal, 1970) Sedimentology has been described by Kazi (1968) and Farshori and Ahmad (1969). [12]Kassi (1986) described the sandstone petrography and provenance of the formation of Kach, Degari, Murree Brewery and Bibi Nani areas and mutually compared and classified them.

[13]The present paper is an attempt to describe the sedimentology of the formation in Kach area with the help of data acquired about sedimentary structures, palaeocurrents and lithofacies associations.

PAK-20: PRELIMINARY PETROCHEMICAL STUDY OF THE CHILAS COMPLEX, KOHISTAN ISLAND ARC, NORTHERN PAKISTAN

[1]The Chilas complex represents lower level rocks of the Late Jurassic- Cretaceous Kohistan island arc. [2]It extends for 300 km from Nanga Parbat through Swat to south-central Dir and attains a width of 40 km in the middle (Fig.1). [3]The field relationship, petrography and chemistry of the different parts of this extensive horizon have been described by several workers (Jan and Mian, 1971; Jan and Kemp, 1971; Chaudhry et al., 1974, Shams, 1975; Jan, 1977a; 1980; Jan and Howie 1980; Jan et al., 1984; Asif et al., 1985). [4]Majority of the rocks correspond to feldspathic gabbronorite composition and consist of plagioclase (An4,-61), ortho- and clinopyroxene with small amounts of quartz, opaque minerals (magnetite, titanmagnetite, ilmenite), hornblende, biotite, and apatite. [5]The intermediate members contain a relatively higher proportion of quartz and may also contain some K-feldspar. [6]Scapolite occurs in a few rocks but garnet is restricted to secondary veins. [7]The rocks display features typical of layered complexes, i.e., rhythmic layering and graded and current bedding. [8]While many of the layers are noritic, some are pyroxenitic, anorthositic, peridotitic and troctolitic (see Jan, 1980, p.102). [9]The rocks were considered to be of igneous origin by earlier workers. [10]On the basis of petrographic and mineralogic characters, Jan (1977a) and Jan and Howie (1980) considered these to be of meta-ig-

neous origin having been uniformly crystallized under pyroxene-granulite facies environments at about 800C under 5.5-7 kb pressure.

[11]Small to large masses of amphibolites (metamorphosed gabbronorite and related rocks) occur intimately associated with pyroxene granulite (gabbronorite) and make over a forth of the belt. [12]On the basis of similar chemistry, Jan (1980) considered the two types of the rocks to be cogenetic and pointed two possibilities for the production of the two different types; (a) either both represent recrystallised norites at similar temperature and pressure at the same time and the availability of water having played a role in producing hornblende instead of pyroxene or (b) the amphibolites, especially abundant along the southern margin of the granulite belt, are retrograde products of the granulites, mainly due to influx of water during the obduction of the latter. [13]The gabbronorite and amphibolites together with related rocks have been classified as the main noritic association by Jan et al., (1984) and Asif et al., (1985).

[14]Apart from amphibolites, large bodies of ultramafic rocks including dunite, peridotite, chromitite, pyroxenites, troctolite, norite, anorthosite and pyroxene- olivine pegmatites, seemingly intrusive in gabbronorite and recrystallized in granulite facies occur in the Chilas complex. [15]Such rocks as a whole have been classified as ultramafic association by Asif et al., (1985; see also Jan et al., 1984). [16]Olivine is an important constituent of the ultramafic rocks and troctolites which are characteristically devoid of quartz, biotite and apatite. [17]The pyroxenes and plagioclase (An95-69) of these rocks are more basic as compared to those in rocks of the main noritic association, whereas the dominant opaque minerals are chrome spinel and some sulphides. [18]Sedimentary structures, particularly layering is more common than in rocks of the main noritic association.

[19]The aim of the present study is to present some new chemical data (see Table 1) describe affinities and igneous crystallization histories of the various rock types and investigate their genetic relationship. [20]Sixty four samples from the various rock types of the two associations (new data; for details see Table 1; Fig.2) in conjunction with one corona gabbro and four norite analyses (Shams, 1975) have been used for plotting on various diagrams.

PAK-21: PETROLOGY OF THE SWAT AMPHIBOLITES AND THE DEVELOPMENT OF A "LESSER HIMALAYAN" BASIN

[1]The northern margin of the Indian plate in northwestern Pakistan is terminated by the Main Mantle Thrust (MMT), an extension of the Indus suture (Tahirkheli and Jan, 1979; Coward et al., 1982, 1986). [2]To the south of the MMT lie schists and gneisses, with marble and amphibolite intercalations (Fig. 1), that constitute part of the Indian plate. [3]The actual margin is probably subducted deep below the suture (Malinconico, 1982), but parts of it are exposed where southward vergent thrusts have piled up slices of metamorphic rocks to form the Lesser Himalayas (Coward et al., 1982, 1986; Humayun, 1985). [4]The rocks here have been assigned ages from Precambrian to Palaeozoic (Le Fort, 1975; Tahirkheli, 1982).

[5]In the Swat Valley, a stratigraphic sequence of gneisses overlain by amphibolites, marbles and graphitic schists was recognized by Martin et al., (1962). [6]The Swat gneisses, part of a belt of augen gneisses extending along the entire Lesser Himalayas (Le Fort et al., 1983), are unconformably overlain by a formation of amphibolites, schists and calcsilicate marbles. [7]These rocks are in turn overlain by dolomitic marbles and calcschists that are followed by thick graphitic schists. [8]The gneisses and overlying rocks form a large thrust sheet, at the base of which occurs a broad mylonite zone (Humayun, 1985).

[9]The amphibolites were previously considered to be recrystallized sediments (Kazmi et al., 1984). [10]Detailed investigations near Mingora on the amphibolites however, indicate an igneous parentage of continental flood basalt (CFB) affinity for the protolith. [11]This requires a reinterpretation of the available data.

[12]Reconnaissance visits to Buner, Malakand, Alpurai and Besham confirm the extent of the Swat sequence (Fig. 1). [13]The sequence is best exposed in the Swat valley and becomes increasingly disturbed towards the Indus valley where the exposures are dominated by mylonitised gneisses. [14]The structural relations of these rocks in the Indus valley were described by Coward et al., (1982). [15]The rocks are younger than the underlying Precambrian-Early Palaeozoic basement, and are Middle Palaeozoic in age (Martin et al., 1962).

[16]Lithologic relations were obscured during Barrovian metamorphism and deformation. [17]The metamorphism is associated with the main Himalayan orogeny (Maluski and Matte, 1984). [18]Metamorphism up to almandine amphibolite facies was followed by retrogression during uplift resulting in the local development of epidote and chlorite. [19]Both staurolite and kyanite have been widely reported from the region (Coward et al., 1982). [20]Garnet-staurolite schists are intercalated with the amphibolites, refuting earlier opinion (Kazmi et al., 1984) that the metamorphism of the region is upper greenschist.

PAK-22:: GEOLOGY AND PETROLOGY OF THE MALAKAND GRANITE, GNEISS AND METASEDIMENTARY COMPLEX

[1]The Malakand granite is one of the well known granites of the north-western Himalayas occurring at longitude 34-36' E and latitude 70-52' N (Toposheet 38 N/14, Survey of Pakistan), along main Mardan-Swat road. [2]Several workers have investigated the various aspects of this granitic body (Khan, 1965; Chaudhry et al., 1974, 1976). [3]The granite has intruded gneisses and metasediments of possible Cambrian and Precambrian age (Kempe, 1983; Shams, 1983).

[4]The Malakand granite is an oval shaped body which covers an area of about 40 sq.km. (Fig.1). [5]At the contact, the rock is fine-grained and is chilled against the metasediments and gneisses. [6]Granitic veins intruding the metasediments and gneisses are also common. [7]The development of garnet due to the thermal effect of granite has been noticed in the large metasedimentary block occurring within the granitic body at Tor Mor Rest House, at Malakand proper (main granite-schist contact) and in granitic gneisses intruded by small granitic veins near Jolagram. [8]The Malakand gneisses make an anticlinal outcrop with the nose plunging approximately ESE and the Malakand granite intrudes the core of this anticlinal structure (Shams, 1983). [9]The gneisses generally trend NE-SW and dip SE. [10]The contact between the granite and gneisses is generally sharp but near the entrance of hydraulic tunnel (Fig. 1) gneisses have equilibrated with granite during the emplacement of the latter type and can only be distinguished on the basis of the presence of garnet in gneisses and the high proportion of amphibole in granite. [11]The gneisses are variably mixed with schistose rocks at the back of Gibraltar (Fig. 1).

[12]We present here a detailed map and petrography of the Malakand granite, gneiss and metasedimentary complex, the major element chemistry of the Malakand granite and the associated gneisses and possible petrogenetic interpretations based on these data.

PAK-23: PETROLOGY OF THE BIBAI VOLCANICS, NE BALUCHISTAN

[1]In northeastern Baluchistan the upper part of the Parh Formation (Cretaceous) shows evidence of widespread volcanic activity. [2]The limestones in this formation contain volcanic ash, extensive laterite beds, some of which still retain tell-tale signs of having been altered from lava flows, and a widespread regional unconformity near the top. [3]In the Kach area, about 45km NE of Quetta, a thick succession of volcanic ash, tuffs, agglomerates and basaltic lavas is seen. [4]These rocks, earlier referred to as the Bibai Formation (Kazmi, 1955, 1979), overlie the Parh Formation and are overlain by the Dungan Formation (Fig.1). [5]In this paper the petrography of the Bibai volcanics and their bearing on the regional environment and tectonics is briefly discussed.

[6]The following rock formations are exposed in the Kach area. ...

[7]The Bibai Formation is comprised of two distinct lithostratigraphic zones; a lower zone which consists entirely of agglomerates, tuffs and lava flows and an upper zone which comprises ash beds tuffs, sandstones, mudstones and conglomerates (Fig.2). [8]The lower zone is irregular and of variable thickness. [9]It is best developed east of Ahmadun and wedges out westwards. [10]It comprises of discontinuous wedges, lenses and patches of agglomerates and lava flows lying on the eroded surface of Parh limestone. [11]Interbedded with the lavas are thin, isolated wedges of Parh limestone (Fig.2). [12]These lenses of Parh contain Globotruncana lapparenti and G. linnei indicating a Campanian age for the lavas. [13]The upper part of the Bibai volcanics contains, amongst others, Omphalocyclus macropora, Obitoides sp., and Baculites binodosus which suggest a Maestrichtian age. [14]The Bibai volcanics may be, therefore, correlated with the Moghal Kot Formation (Williams, 1959) and Fort Monroe Formation (Shah, 1978).

[15]Structurally the Kach area forms part of the allochthonous zone which is traversed by a number of thrust faults, including the Gogai and Bibai nappes (Kazmi, 1979). [16]In this region outcrops of Bibai Formation form a thrust sheet (Bibai nappe) which overlies the Ghazij and at places the Dungan Formation (Figs.1 and 2).

PAK-24: ULTRAMAFIC AND MAFIC ROCKS OF THURLY GAH AND THEIR RELATIONSHIP TO THE CHILAS COMPLEX, N. PAKISTAN

[1]The Chilas complex, a 300 km long and up to 40 km wide lopolithic body of norites and associated rocks is probably the largest single mass of its type in the world. [2]It holds a significant geological position in the Kohistan sequence, a recently recognized remnant of a Mesozoic intra-oceanic island arc entrapped between the colliding Indian and Eurasian plates (Tahirkheli et al., 1979; Bard et al., 1980; Bard, 1983ab; Coward et al., 1982, 1985). [3]The predominantly noritic complex locally contains several isolated bodies of ultramafic rocks, especially in the vicinity of Chilas. [4]These, accompanied by a series of mafic differentiates, constitute an association whose field, petrographic, and chemical characteristics are distinct from those of the main noritic rocks of the complex (Jan et al., 1984; Asif Khan et al., in prep.).

[5]Petrographic accounts have been presented from various parts of the Chilas complex (i.e., Jan, 1970, 1979; Desio, 197; Shams, 1975 from the Indus Kohistan; Jan and Mian, 1971; Jan and Kempe, 1973 from Swat Kohistan; and Chaudhry et al., 1974 from Dir Kohistan). [6]Recently, Jan et al., (1984) have given a comprehensive field and mineralogical account of the constituent rock-types of the Chilas complex. [7]The present study is a further attempt to elaborate these aspects of the complex, with emphasis on the study of (1) mode of emplacement of the ultramafic and associated mafic rocks in the earlier main norite rocks of the complex, and (2) mutual relationship between the differentiated ultramafic and mafic rocks, and of these rocks with the main noritic rocks of the complex.

[8]During the course of this work, we have restricted ourselves to a detailed study of a single occurrence of the ultramafic and associated mafic rocks exposed at the mouth of Thurly Gah. [9]These were selected due to their easy access and reasonably large aerial extent (Fig 1). [10]The studied area is located on the Karakoram Highway (KKH), about 30 km west of Chilas (long. 73 50'E., lat. 3535'N.) [11]A field work of two weeks was carried out during Christmas 1983, followed by several short revisits, and consisted mainly of geological mapping on a scale of 1 cm = 200m. [12]Most of the 90 samples collected from different lithological units were cut into thin sections for textural and modal studies. [13]Additionally, a number of microprobe and whole rock analyses were carried out by M.A.K. (at Leeds and Leicester Universities and, lately, in the Imperial College, London) and by M.Q.J. (at Leicester and Peshawar Universities); details of these would be presented subsequently.

PAK-25: MINERALOGY OF THE BLUESCHIST FACIES METAGRAYWACKE FROM THE SHERGARH SAR AREA, ALLAI KOHISTAN, N. PAKISTAN

[1]The Main Mantle Thrust (MMT) marks the convergent plate junction where rocks of the Cretaceous Kohistan island arc are obducted onto the Indian plate (Jan and Symes, 1979; Tahirkheli et al., 1979; Dewey and Burke, 1973; Molnar and Tapponnier, 1973; Bard, 1983). [2]The origin and tectonic evolution of the Kohistan island arc are attributed to rapid convergence which resulted in the consumption of Tethyan oceanic crust and upper mantle along a northward dipping subduction zone (Tahirkheli et al., 1979; Klootwijk, et al., 1979; Andrew-Speed and Brookfield, 1982; Coward et al., 1982; Bard, 1983; Majid and Paracha, 1980). [3]The MMT zone is regarded as the western continuation of the Indus Zangbo suture zone and is characterized by tectonic slices.

[4]This zone in Swat and Kohistan comprises widely distributed peridotite, their serpentinized equivalents and tectonic melanges. [5]Beside greenschists and ophiolites which are the most abundant rocks in the melange, local occurrences of high-pressure low-temperature metamorphic rocks have been reported from the Shangla section in Swat. [6]Such rocks have also been found in the Indus- Zangbo suture zone in Ladakh and eastern Tibet (Jan, 1985).

[7]Petrographic account of the blueschist facies rocks from Swat are given by Shams (1972, 1980), Jan et al., (1981) and Kazmi et al., (1984). [8]Presence of jadeitic pyroxene (Guiraud et al., in prep.) and aragonite (Davies, 1962) in these rocks suggests high-P and low-T metamorphic conditions (about 7 kbars and 380C, Jan et al., 1981) during Late Cretaceous (Shams, 1980; Kazmer et al., 1983; Maluski and Matte, 1984). [9]Zoning in amphibole grains in these rocks has been interpreted as a consequence of oscillatory transition between greenschist facies and epidote-amphibolite facies metamorphism (Guiraud et al., in prep.). [10]Beside Shangla in Swat, blueschist facies rocks were found by the authors in the Allai Kohistan section of the Indus suture zone during a field trip in summer, 1984 to Shergarh Sar area. [11]This newly found occurrence is described in detail in this paper.

PAK-26: SHEAR WAVES PROVIDE AN EXTRA CONTROL ON SEISMIC INTERPRETATIONS

[1]In recent years shear waves have been commonly used in seismic work for the exploration of hydrocarbons, earthquake predictions, and crustal seismology. [2]These waves differing from P-waves in physical nature and characteristics respond differently to varied conditions of porosity, saturation, saturating fluids, and lithology. [3]For example, porosity of a rock reduces both velocities (Vp, Vs) but Vs appears to be more sensitive to pore aspect ratio (Tatham, 1982), under-saturation causes Vp to decrease more than Vs (O'-Connell and Budiansky, 1974; Toksoz, et al., 1976), and an increased amount of quartz in a rock would enhance Vs but suppress Vp. [4] This differential behaviour of Vs is of great significance in explaining situation like Vp- overlaps in different lithology. [5]The Vp/Vs which fluctuates abnormally in such anomalous situations is likely to provide an invaluable tool for earthquake predictions (Aggarwal, et al., 1975), the detection of gas saturation from the zones where reflection amplitudes are unreliable (Tatham, 1976).

[6]The emphasis in this paper is on the contribution of shear waves in solving lithologic problems which may not be solved by Vp alone. [7]For that study the LUST (Lewisian Units Seismic Traverse) data are taken into account; LUST is a 40km long refraction profile (Fig. 1) across laterally varied lithology of (central and northern belts) the Lewisian metamorphic complex of NW Britain, and shot (underwater) from both ends (Badcall and Durness) and on two intermediate positions (Laxford and Inchard). [8]Lithologically, the northern belt of the complex predominates in quartz-feldspathic gneisses (acidic composition) and contains some concordant amphibolite layers; the central belt comprises mainly pyroxene-granulites (andesitic composition) and retrogressed equivalents. [9]The boundary between these two assemblages referred to as the Ben Stack Line, forms a crustal lineament and contains a concentration of granites and pegmatites (Pecah, et al., 1907; Holland and Lambert, 1973; Bowes, 1978).

PAK-27: TECTONIC SIGNIFICANCE OF MYLONITES FROM MINGORA, SWAT

[1]The geology of Mingora is dominated by the Main Mantle Thrust (MMT) which is the western extension of the Indus-Tsangpo suture zone (Jan et al., 1981a). [2]The MMT marks the collision of the northern margin of the Indian plate with the Kohistan island arc (Tahirkheli et al., 1979). [3]The suture zone has been depicted as a region of multiple thrusts, imbricate faults, and nappe formation (Dargai klippe), however, no direct evidence of thrusting has been recorded in the basement in support of this concept (Tahirkheli et al., 1979; Bard et al., 1980; Kazmi et al., 1984). [4]Geophysical data, although, suggest the presence of sialic material upto a depth of 100 kms (Malinconico, 1982).

[5]Present studies identify a large mylonite zone in the basement of the Indian plate and extensive shearing, deformation and subsequent metamorphic recrystallization, probably related to the obduction of the Kohistan island arc. [6]These findings will require major revision of the stratigraphic setup and the chronology of metamorphic and structural events.

PREVIOUS WORK: [7]The initial work on the geology of Swat by Martin et al., (1962), has been subsequently revised by the application of plate-tectonic concepts (Jan et al., 1981a; Tahirkheli et al., 1979; Kazmi et al., 1984). [8]Martin et al., (1962) classified the granitic rocks of Swat and Buner into two groups: the Ambela Granite intruding the Swabi-Chamla sedimentary group in the south, and the Swat granitic gneisses intruding the Lower Swat-Buner schistose group in the north. [9]They suggested that the Swat granitic gneisses intrude the lowest unit of their schistose group, the siliceous schist, in the form of a thick concordant sheet It is this unit, and its relationships with the gneisses and other schistose units that has undergone major revision by Kazmi et al., (1984) and the present studies.

[10]Kazmi et al., (1984 considered the gneisses to be intruded into the siliceous schists (renamed as Manglaur crystalline schist) and proposed a major unconformity between this Precambrian-Cambrian basement and the overlying Alpurai schists and Saidu schists. [11]The Swat granitic gneisses are considered to be part of the type granite-gneiss belt that extends along the northern margin of the Indian plate (Jan et al., 1981b) from Malakand to Nanga Parbat and possibly along the entire length of the Lesser Himalayas (Le Fort et al., 1983). [12]These gneisses are, therefore, correlatable with the Mansehra Granite having a Rb/Sr whole-rock isochron of 516 + 16 m.y. (Le Fort et al., 1980) and the Simchar pluton of Nepal with a similar age (Le Fort et al., 1983).

PAK-28: MAJOR AND TRACE ELEMENT VARIATIONS IN THE LAVAS OF SHERGARH SAR AREA AND THEIR SIGNIFICANCE WITH RESPECT TO THE KOHISTAN TECTONIC ANOMALY

[1]Rocks of the Shergarh Sar area (3450' 15"N - 3454' 15"N and 731'E-735'E, Sheet No. 43F/1), in Allai Kohistan of Hazara division have been distinguished into three tectono-stratigraphic groups. [2]From south to north in the type Bana-Baracher section of the studied area occur (1) rocks of the Indo- Pakistan subcontinent sequence, (2) rocks of the Indus suture melange, and (3) amphibolites of the Kohistan island arc (Fig 1).

[3]According to Shah (1985), the Indo-Pakistan subcontinent sequence in the area includes granite gneiss, thin-bedded crystalline limestone, quartz-mica schist, graphitic schist and phyllite. [4]The Indus suture melange is comprised mainly of ultramafic rocks, pillow lavas with associated metachert and limestone, green-schists, and blueschist facies metagraywacke. [5]The amphibolites of the Kohistan island arc have been distinguished into epidote- amphibolite and locally developed garnet epidote-amphibolite. [6]These are of great significance from the standpoint of stratigraphy and tectonics of the Allai Kohistan.

[7]Within the Indus suture melange, the dominant rocks are the basic volcanics characterized by pillow structures. [8]These have a thrust contact with the associated ultramafics which are in places highly fractured and brecciated. [9]In this paper, the general field and thin section's characteristics along with a detailed chemical account of the pillow lavas from the studied area are described.

PAK-29: CORONITES FROM THE CHILAS AND JIJAL-PATAN COMPLEXES OF KOHISTAN

[1]The Chilas complex, up to 40 km in breadth, is a stratiform lopolith stretching west-east for 300 km from Dir to Astor. [2]It consists predominantly of noritic rocks with subordinate ultramafic rocks, troctolites, anorthosites and hypersthene-quartz diorites metamorphosed under pyroxene granulite facies conditions. [3]The complex is emplaced in amphibolites and is intruded on its north by quartz diorites and tonalites. [4]Megascopically identifiable coronas occur in several places

in the complex. [5]These coronites range from feldspathic peridotites to pyroxenites, troctolites, olivine gabbros, and a few norites and anorthosites with highly calcic plagioclase. [6]Olivine coronites were briefly described from Chilas by Shams (1975), Khattak and Parvez (1982), and Bard (1983), and from Swat by Jan (1977), and Jan and Howie (1981a).

[7]Corona development has also taken place locally in the Jijal-Patan area. [8]Here a 200 km2 wedge-shaped complex comprises a series of ultrabasic-basic rocks that may be magmatically related to the Chilas complex. [9]These rocks have been metamorphosed to garnet granulites at 800-850C, 12-14 kbar (Jan and Howie, 1981b; Coward et al., 1982; Bard, 1983). [10]The southern 1/3rd of the complex, however, is occupied by a thick slab of alpine-type (ophiolitic) ultramafic rocks devoid of garnet.

[11]In this paper we present an account of the various types of coronas found in the two complexes. [12]Several dozen thin sections of the coronites were studied and hundreds of microprobe analyses have been performed at the universities of Leicester and Peshawar by M.Q. Jan. [13]Details of phase chemistry will be presented in joint papers with B.F. Windley.

PAK-30: PETROCHEMISTRY OF THE ROCKS FROM BABAJI AREA, A PART OF THE AMBELA GRANITIC COMPLEX, BUNER NORTHERN PAKISTAN

[1]Syenites, quartz-syenites and granites are the major rock types in the Babaji area of Buner, Swat District. [2]These rocks extend from Bagh Banda in the west to Kuliari village in the east (Fig. 1). [3]The Babaji rocks constitute the northern portion of the Ambela Granitic Complex and have sharp contacts with metacalcareous rocks towards north. [4]The constituent rocks from the studied area are possibly of Early Tertiary age (Siddiqui et al., 1968; Kempe, in press), intruding the Lower Swat-Buner Schistose group of Palaeozoic age (Davies et al., 1963).

[5]The region was first geologically investigated by Martin et al., (1962). [6]Later, Siddiqui (1965) and Siddiqui et al., (1968) investigated the Babaji syenites and considered them to be comagmatic with Koga syenites. [7]Kempe and Jan (1970) and Kempe (1973) included the Ambela Complex in their alkaline igneous province. [8]East and west of the Complex, there are abundant occurrences of intimately associated contemporary igneous rocks in an arcuate belt which extends from Mansehra and Tarbela in the east through Utla, Ambela and Warsak to Khyber Agency in the west (Kempe and Jan, 1980).

[9]This paper presents a detailed account of the petrography and geochemistry of the three major rock types, i.e., syenites, quartz-syenites and granites from the Babaji area of the complex. [10]A geologic map has been prepared (Fig. 1) on toposheet No. 43B/11 with 1:50,000 scale. [11]One hundred and twenty hand specimens were cut in thin sections and studied under microscope, 19 were selected for chemical analyses. [12]I.U.G.S. system of nomenclature has been adopted for classification.

Appendix E-3

Native Geolgoy RA Discussions used in the study

NS-01: Tolbachite, CuCl2, the first example of Cu2+ octahedrally coordinated by Cl-

[1]Tolbachite contains Cu2+Cl octahedra distorted such that there are four Cu-Cl equatorial bond distances [2.263(6) A] and two much longer Cu-Cl apical bond distances [2.991(6)A], a (4+2) distortion. [2]This octahedral environment is a result of the well-known Jahn-Teller effect. [3]Each CuCl octahedron shares two Cl-Cl edges with adjacent octahedra, and its apical Cl-ions are equatorial ligands for adjacent octahedra. [4]This linkage results in corrugated octahedral sheets (Fig 2) of composition CuCl2 parallel to (001). [5]Each sheet is electrostatically neutral, and linkage between adjacent sheets is by Van der Waals forces, explaining why tolbachite quickly hydrates in air.

[6]This study provides bond-distances for a (4+2)-distorted Cu2Cl6 octahedron.

[7]Six examples of Cu2+2r octahedral bond distances observed in mixed-ligand copper oxysalt minerals are given in Table 2. [8]All such octahedra are (4+2)-distorted, and the pseudo-Jahn-Teller effect is a controlling factor in determining the bond-distance distributions. [9]All Cu2+6 (= O2,OHI,H2O,Cl) octahedra show the Cl ions to be preferentially located at the apical positions of the (4+2)-distorted octahedra. [10]The only examples so far observed of Cu23 octahedra with Cl in the equatorial positions in mixed-ligand octahedra occur when there are more than two Cl ligands involved: where there are four Cl-ligands, two occur in the apical positions and two occur in equatorial positions (Table 2).

[11]The observed (Cu2+-Cl,3,,0n,l) distances in eriochalcite and chlorothionite (2.29 and 2.25 A respectively) are close to the analogous value in tolbachite (2.26A), indicating that these are typical equatorial bonds in the mixed-ligand structures.

[12]The (Cu2+-Cl) distances in the mixed-ligand minerals lie in the range 2.75-3.05 A, as compared with the value of 2.99 A in tolbachite. [13]The wider range of apical vs equatorial distances is similar to that observed in Cu2+(02-, OH, H2O)3 octahedra, suggesting that the anharmonicity in the Cu2+-Cl potential is similar to that found for the Cu2+-O potential (Burns and Hawthorne, unpublished manuscript, 1992).

[14]Note also that the Cu-Cl apical distances are generally shorter in the mixed-ligand structures than in tolbachite; >

it will be interesting to see (by means of molecular-orbital calculations) if the presence of O equatorial ligands tends to shorten the apical Cu2-Cl distances.

NS-02: Kinetics of the marcasite-pyrite transformation: An infrared spectroscopic study

[1]The experimental data presented here are consistent with the previously reported time, temperature, and solid-state transformation results of Fleet (1970) referred to in the introduction. [2]Kjekshus and Rakke (1975) observed that at 573 K, heat treatment under vacuum for up to 14 months does not induce changes in marcasite samples, whereas at 623 K after the same period, mixtures of marcasite and pyrite are obtained. [3]At 673 K, mixtures of marcasite and pyrite are produced after heating for one month.

[4]Estimates of the time taken for a given fraction () of pyrite to be produced from marcasite can be made using the activation energy and frequency factor obtained above. [5]A rate constant is derived from the Arrhenius equation for the temperature of interest, and the time taken for a given pyrite fraction () to be obtained is calculated from the following form of the Johnson-Mehl equation: [...].

[6]Calculations using the values Ea and A derived above and with m = 2 suggest that transformation of half of the marcasite to pyrite takes place in approximately 6d a 673K, in 205d at 623K, and in 40yr at 573K.

[7]These estimated values, which should be used as a guide only, are consistent with the reported experimental values of Kjekshus and Rakke (1975). [8]That would suggest that a similar transformation mechanism occurs at lower temperatures, although at considerably slower rates.

[9]Murowchick and Barnes (1986) suggested that the temperature-dependent distribution of marcasite in the Salton Sea geothermal field indicates that temperatures of below 433 K are needed to preserve natural marcasite over a multimillion-year time span. [10]This theory is based on studies by Rising (1973) and McKibbin and Elders (1985).

[11]A half-life for the solid-state transformation of marcasite to pyrite estimated from the above data at 473K is 3 x 10 yr, whereas at 433K, calculations give a half-life of 13 x 10yr.

[12]These half-lives show a consistency with the proposal of Murowchick and Barnes (1986).

[13]Again, these figures should be used with caution, taking note of the limitations of extrapolating higher temperature kinetic data to lower temperatures, and the possible dangers of inferring that the reaction mechanism is the same throughout the temperature range.

[14]It is, however, kinetic factors and not thermodynamic stability that ensure long-term preservation of the marcasite structure in natural systems.

[15]If marcasite is slightly S-deficient compared with pyrite, as was proposed by Buerger (1934), then ready availability of aqueous S species in hydrothermal systems could speed the transformation to pyrite by a diffusion process (H.L. Barnes, personal communication, 1992).

[16]However, from values of m tabulated by Hancock and Sharp (1972) for various solid-state reactions, the marcasite to pyrite transformation in this experiment corresponds to a nucleation and growth mechanism rather than to a diffusion process. [17]Although Christian (1975) cautioned against proposing a mechanism simply from the values of m obtained in the kinetic analysis of a transformation, examination of the crystal structures of marcasite and pyrite suggests that a nucleation and growth model for the isochemical transformation is more plausible than transformation by diffusion. [18]Furthermore, the suggestion by Fleet (1970) that the structural reorganization involved in the transformation is minimal implies negligible diffusion of Fe and S within the transforming crystal matrix.

[19]A nucleation model is in agreement with the observation that rotation of half of the S2 groups in marcasite by 90 would result in the pyrite structure (Tossell et al., 1981). [20]This would involve breaking one of the three S-Fe bonds on each end of the disulfide link in order to allow rotation to occur. [21]The Fe-S bonds most likely to break are those forming the four-membered rings arising from edge-sharing octahedra in the marcasite structure. [22]These are the structural features under most strain during heating. [23]Breaking these bonds would allow the S-S group to invert, and new Fe bonds to attach to the S opposite to the former Fe-bonding position on the S (Fig 6). [24]It is unlikely that the S-i bonds in the structure are broken.

[25]Christian (1975) summarized values of m from the Johnson-Mehl equation that describe various models of polymorphic transformations. [26]A value of $m=2$ corresponds to a grain-edge nucleation model. [27]The pyrite nuclei formed by such a process could then grow along and outward from the marcasite grain edge forming the commonly observed intergrowths (Fleet, 1970) of marcasite {101} parallel to {001} of pyrite.

NS-03: Sieve-textured plagioclase in volcanic rocks produced by rapid decompression

[1]Our experimental procedure involves three assumptions in relation to the magmatic processes being modeled. [2]First, decompression rates and intervals are reasonable analogues of natural conditions. [3]Second, heat loss is insignificant compared with the decompression rate, such that the process is nearly adiabatic. [4]Third, over the pressure intervals considered, adiabatic decompression is nearly isothermal – otherwise significant cooling will counteract the effects of decompression. [5]On the other hand, raising the temperature of the system by magma mixing will promote dissolution of plagioclase. [6]However, we will consider the case of decompression without magma mixing.

[7]In regard to the third assumption, adiabatic cooling must be less than the depression of the plagioclase liquidus caused by decompression. [8]A liquid of composition AbAnDi at 1425°C has an adiabatic gradient of 1.5C/kbar (calculated from Rivers and Carmichael, 1987), cooling the liquid just 3-9°C for the pressure intervals (2-6 kbar) in this study. [9]In a crystal-bearing magma, there is a second component to the total adiabatic gradient as latent heat is extracted from the liquid as the crystals resorb, resulting in further cooling of the system at equilibrium. [10]Unlike the adiabatic gradient of a pure liquid, the extraction of latent heat is limited by the rate at which the crystals can resorb. [11]Therefore, as long as resorption is incomplete, a rapidly decompressed magma is apt to be superheated with respect to its total adiabatic gradient.

[12]Morse (1980) provided a convenient review of pertinent experimental data regarding the relative effects of isothermal decompression and adiabatic cooling. [13]Albite has a liquidus with a slope of 10C/kbar, and the liquidus of intermediate plagioclase (An40) is lowered by about 4C/kbar about three times that of the liquid adiabat. [14]However, as shown above, the effect of pressure is enhanced in multicomponent systems, whereas adiabatic gradients are not nearly as compositionally dependent. [15]Morse (1980) reviewed data showing that the Di-An eutectic is lowered on the order of 10C/kbar. [16]Gill (1981) noted that plagioclase is the liquidus phase in almost all andesites; thus, the whole rock liquidus represents a plagioclase liquidus, albeit independent of composition. [17]At pressures less than 15 kbar where plagioclase is on the liquidus and the liquidus is least sensitive to pressure, dT/dP is still about 5C/kbar (Green and Ringwood, 1968). [18]In addition, Figure 2 shows that changing pressure also changes the equilibrium plagioclase composition, providing a further driving force for resorption.

[19]Therefore, we employed isothermal experiments as an approximation of natural processes, as the effect of pressure must be at least several times that of the adiabatic gradient.

[20]We produced strong resorption textures in plagioclase for decompression rates equivalent to rapid ascent rates (210 m/s). [21]Therefore, resorption must also occur for a range of decompression rates less than this.

[22]Previous studies have determined magma ascent rates of up to 0.7 m/s for Mount St. Helens (Scandone and Malone, 1985) and 1.7 m/s beneath Kilauea (Klein et al., 1987), whereas Spera (1980) calculated minimum ascent rates of O.5m/s based upon the settling velocity of ultramafic nodules in basaltic magma. [23]These data indicate that ascent rates in nature can be within at least an order of magnitude of our experimental rates.

[24]Because the upper range of magmatic ascent rates may not be obvious to all, we constructed Figure 6 in order to evaluate possible ascent rates in magmatic systems with established conduits. [25]Figure 6 is intended to illustrate the approximate scale (order of magnitude) of potential magma ascent rates: It is not a rigorous model. [26]We assume the flow of a Newtonian fluid through a dikelike conduit, where the viscosities and density contrast between magma and wall rock used to derive the curves were treated as constants, although they vary somewhat with pressure (Kushiro, 1980).

[27]A model calculated for a tabular, rather than a cylindrical conduit, geometry provides a more conservative estimate of ascent rates because it takes into account the larger component of frictional resistance between the magma and wall rock.

[28]The details of the calculation of the curves (Fig 6) are only modestly dependent on the model. [29]Magma ascent rates in conduits of varying geometry (e.g., Spera, 1980, p 280-281; Kushiro, 1980, p 117) are proportional to the density contrast and inversely proportional to the viscosity. [30]However, ascent rates are also proportional to the square of the conduit width or radius, depending upon the geometry, causing this term to dominate the model. [31]As a result, the calculations vary only by a factor of about 2-3, given reasonable variations in the density contrast (0.2-0,3 g/cm3) independent of conduit geometry. [32]Therefore, it appears that magma ascent rates may be very rapid, approaching our decompression rates over a range of geologically reasonable conditions. [33]Magmas always contain a volatile component, and modest concentrations of H20 (0.25 wt%) and C02 (0.5 wt%) can result in the reduction of viscosity by an order of magnitude in silicate liquids (White and Montana, 1990), thereby enhancing ascent rates.

Observations for natural systems

[34]Our experimental results provide a basis for interpreting magmatic processes in volcanic rocks containing coarse sieve-textured plagioclase.

[35]The phenocrysts in Figure 1 are, on average, 10-20 times larger in section than those in our experiments, which develop similar textures after 4-12 h.

[36]If resorption scales linearly with crystal size, these textures may develop within a few days for large volcanic phenocrysts, following depressurization of at least 2-3 kbar.

[37]The lava in Figure 1 is strongly porphyritic, with plagioclase phenocrysts occurring in two distinct populations (1) resorbed crystals, and (2) euhedral phenocrysts. [38]The phenocrysts show a fairly continuous size distribution up to a few millimeters, although the resorbed phenocrysts are always the largest crystals in the rock. [39]Compositional profiles in the resorbed crystals are quite complex, exhibiting normal, reverse, and oscillatory zoning. [40]The euhedral phenocrysts never approach the size of the large resorbed crystals (0.5 mm), and usually exhibit normal zoning, although reverse and rare oscillatory zoning are also present. [41]We summarize the compositions of crystal interiors of both populations in Figure 7 to help interpret this sample. [42]Despite a compositional overlap between resorbed and unresorbed plagioclase, small euhedral plagioclase phenocrysts tend to range to significantly more calcic compositions. [43]One analysis of resorbed plagioclase is distinctly An-rich and may represent a Ca-rich sector in a zoned crystal.

[44]Many of the compositional and textural aspects of the phenocrysts may be antecedent to those features imposed by decompression. [45]Therefore, in light of our experiments, we outline a subset of the characteristics of the sample in Figure 1 that may result from rapid pressure release. [46]We suggest that the large resorbed plagioclase samples represent partial crystallization of a magma at depth. [47]Their subsequent resorption was initiated by pressure release accompanied by relatively little heat loss as the magma ascended to a shallow magma reservoir. [48]As a result of this process, a coarse sieve texture was superimposed on the complex zoning patterns that had already been acquired by these crystals.

[49]Unfortunately, it is nearly impossible to quantify this process. [50]The pressure at which the resorbed crystals formed is difficult to estimate without a suitable geobarometer. [51]Even if a suitable geobarometer existed, the problem would not be solved because uncertainties in calculated pressures are often as large (2-3 kbar) as the decompression,interval required to produce sieve textures.

[52]Likewise, the ascent rate is equally difficult to estimate, as our experiments do not constrain the relationship between resorption textures and the rate of pressure release. [53]However, if the equilibrium composition of plagioclase immediately prior to and after eruption could be determined, it might be possible to estimate the minimum increment of pressure release from Figure 4.

[54]Although it is relatively easy to ascribe first-order features like coarse sieve textures to decompression, the explanation of other compositional and textural features is more tenuous.

[55]Perhaps the nucleation of euhedral calcic microphenocryst cores was in response to new conditions of equilibrium at a substantially reduced pressure, and normal zoning of these crystals may have been in response to subsequent cooling and evolution of the liquid, as reflected in their compositional variation (Fig 7). [56]On the other hand, the reversely zoned euhedral crystals are more problematic. [57]They may reflect phenomena such as crystal growth in a continually ascending magma in which plagioclase compositions are increasingly calcic (Fig 2), or crystallization under increasing H_2O pressure (Johannes, 1978) caused by the formation of an anhydrous crystal assemblage after decompression or by a number of other phenomena, as reviewed by Gill (1981). [58]It is difficult to interpret the presence of both normal and reverse zoning in the euhedral phenocrysts from the same sample.

[59]Zoning in plagioclase is a complex problem, underscoring the problematic nature of inferring magmatic processes from plagioclase phenocryst textures (Gill, 1981).

[60]In general, the nucleation of new calcic crystals, rather than calcic overgrowths on the sodic plagioclase, is necessitated by the concomitant dissolution of the sodic crystals. [61]Instances may occur in which resorption is arrested as dissolution kinetics become sluggish when the system approaches its new equilibrium. [62]The resorbed crystals could be subsequently rimmed by calcic plagioclase. [63]Alternatively, degassing or cooling of the magma may also arrest resorption and allow the crystallization of Ab-rich rims. [64]A variety of processes may operate in combination at different times and places within a magma body, giving rise to many of the complex textural features observed in the plagioclase of orogenic magmas.

NS-04: The applicability of least squares in the extraction of thermodynamic data from experimentally bracketed mineral equilibria

[1]Having established that LSQ is an appropriate methodology for extracting thermodynamic data from experimentally bracketed equilibria, the power of LSQ in allowing the calculation of uncertainties in and correlations between the thermodynamic data can be reiterated. [2]An important observation concerning these uncertainties comes from the distribution of d/s for the experimental equilibria (Fig 4) and the shapes of the bracket distribution functions (Fig 5). [3]For d/s 1, i.e., for much of the data, the major component of the distributions relates to the possibility of the equilibria being outside the brackets. [4]As a consequence, the main contribution to the calculated uncertainties is likely to come from the uncertainties on the ends of the brackets, not the width of the brackets themselves.

[5]It is for this reason that Engi and Lieberman (1990), using Monte Carlo simulation in conjunction with MAP to estimate uncertainties on extracted thermodynamic data, reached the erroneous conclusion that uncertainties must be essentially nonexistent.

[6]The formally correct way to proceed in the data extraction problem, treating the LSQ methodology as just a special case of maximum likelihood with the data being Gaussian distributed, would be to derive a method of maximum likelihood using the bracket probability distribution. [7]This is straightforward, but applying it would be tedious because there is no closed form for the solution. [8]Moreover, as the greatest majority of the data are essentially Gaussian distributed and the few remaining equilibria with large d/s, are not critical to the analysis, little would be gained for the considerable amount of extra effort expended.

[9]If entropies, for example, in addition to enthalpies, are also to be constrained in the data extraction, the LSQ logic is still appropriate, if the overall analysis is considered to be iterative, with the focus on enthalpies of formation but with entropies changing between iterations.

[10]We conclude with a quote from DS4: "Both LSQ and MAP are capable of providing reliable and similar analyses of the experimental data, each with its advantages and disadvantages. [11]However, we believe that the ability of the least squares method to provide the uncertainties, and their mutual correlations, of the calculated thermodynamic data makes this [the LSQ method] the preferable method of analysis."

NS-05: Dielectric constants of diaspore and B-, Be-, and P-containing minerals, the polarizability of B2O3 and P2O5, and the oxide additivity rule

[1]Table 3 lists mean dielectric constants and molar volumes of the crystals studied here and the oxides that are used to test the oxide additivity rule. [2]Arithmetic, rather than geometric, mean values are used. [3]Geometric mean values are smaller by 0.0-0.2% for crystals with little or no anisotropy, whereas they can amount to 2.7% for crystals such as $La_2Be_2O_5$, with significant anisotropy. [4]Table 4 lists the total polarizabilities of the ternary oxides and the polarizabilities of B_2O_3 and P_2O_5, derived by subtracting the components of polarizabilities due to the binary oxides. [5]Composite values for D (B_2O_3) of 6.15A and D (P_2O_5) of 12.44 A were extracted from D (B_2O_3 or P_2O_5) = D (complex oxide)-D (simple oxide).

[6]Table 5 compares the total molecular dielectric polarizabilities determined from the measured dielectric constants using the Clausius-Mosotti relationship (Eq 1) and from the oxide additivity rule using what we believe are the most accurate dielectric constants of Li_2O, Na_2O, BeO, MgO, CaO, Al2O£, Nd_2O_3, La_2O_3, SiO_2, and AlOOH (Table 3).

[7]The agreement between the observed dielectric polarizabilities and those calculated from the sum of the oxide polarizabilities according to the oxide additivity rule (Eq 2) is excellent and is comparable to the typical 1% variation observed previously for a series of aluminates, gallates, and silicats (Shannon and Subramanian, 1989; Subramanian and Shannon, 1989, Shannon et al., 1989, 1990, 1991).

[8]The slightly larger deviation of beryllonite might be caused by the inaccuracy of D (Na_2O) estimated from the polarizability of NaF in conjunction with a value of D(O^{2-}) = 2.01 A (Shannon, 1991). [9]It might also be caused by the "rattling cation" effect, which was described by Dunitz and Orgel (1960) as a progressive "loosening of the central cation at the center of its surrounding octahedron to off-center displacements characteristic of ferroelectric and antiferroelectric substances" as the size of the central cation in an octahedron decreases. [10]The polyhedron can adjust its configuration to adapt to the small cation by movement of the cation, the anions, or both resulting in polyhedral distortion such as in the Nal site of beryllonite. [11]When crystal symmetry restricts the motion of both cation and anion such as is observed in cubic pyrope, larger than normal bond distances and thermal motion may occur (Shannon and Rossman, 1992). [12]In both instances evidence for rattling cations can be seen from decreased apparent bond valences or increased thermal motion. [13]Nal, which occupies a nine-coordinated site in NaBePO (Giuseppetti and Tadini, 1973), is characterized by unusually large thermal parameters and by bond valence sums, calculated from the Brown and Altermatt

(1985) parameters, which are somewhat low, 0.87 valence units (vu), relative to its theoretical value of 1.0vu. [14]Na2 and Na3 occupy distorted octahedral sites and have more normal apparent bond valences of 1.06 and 1.15 vu, respectively.

[15]This group of beryllates, borates, and phosphates, along with several other groups of oxides including Y and RE aluminates, chrysoberyl, spinel, olivine-type silicates, phenacite, and zircon form a class of well-behaved oxides whose dielectric polarizabilities follow the oxide additivity rule to +0.5-1.5%. [16]This group forms a basis for comparison with compounds that show larger deviations (5%) because of ionic or electrcnic conductivity, the presence of H2O or CO2, or structural peculiarities (Shannon, 1991). [17]This latter type of deviation is illustrated by several structural groups such as silicate garnets and melilite-type compounds that contain certain members (pyrope, hardystonite, akermanite) that show strong deviations (+5%) from the additivity rule.

NS-06: Formation of fluid inclusions and etch tunnels in olivine at high pressure

[1]It is apparent that impurities on growth dislocations may have influenced the formation of etch tunnels in olivine. [2]We suppose that impurities are present on growth dislocations in San Carlos olivine and that the impurities locally enhance the solubility of olivine in the fluid or lower the melting temperature of olivine in the presence of fluid. [3]Etch tunnels (tubes) begin to form by dissolution or melting of olivine, and the fluid sequesters impurities and provides a high diffusivity pathway for homogenization with the fluid outside the crystal. [4]Later, the tubes heal into linear arrays of bubbles, in order to minimize heir surface energy, and trap the fluid.

[5]The most reasonable interpretation of our fluid-inclusion data is that there were two immiscible fluids present during most of the experiments, a silicate-carbonate-rich melt and a CO2-H2O-rich fluid. [6]Such a silicate-carbonate-rich melt could account for the mostly solid inclusions observed in 111-3°C and 111-2B and also could yield some crystallization of olivine on the tube and inclusion walls, as has been observed. [7]The large compositional variability of the inclusions is interpreted to be the result of trapping different amounts of two coexisting, compositionally different fluids in any given inclusion or of trapping of a fluid whose composition changed with time during tube boring and subsequent (or concurrent?) tube healing. In fact, both processes could have occurred.

[8]Chemical environment and fluid speciation are important aspects of etch tunnel formation in olivine; etch tunnels formed only in samples annealed in the NaCI+ BN pressure assemblies and not in the NaCl pyrex+alumina assemblies. [9]As stated earlier, the NaCl2 BN assemblies stabilize at a much lower 1:2 than the NaCI+pyrex+alumina assemblies, and this would affect the chemical activity and speciation of the fluid.

[10]Additional experiments are needed to elucidate the role of chemical environment in etch tunnel formation. [11]If growth of etch tunnels occurs by dissolution of olivine in the fluid phase, it is difficult to reconcile the correlation of maximum tube length and experiment duration (Table 1) with the observation that all tubes show some evidence of healing.

[12]Longer tubes were produced by longer experiments, suggesting that tube formation continued throughout the experiment. [13]This is an unexpected result if tube growth is controlled simply by dissolution of olivine because the fluid probably is saturated with dissolved solids within several minutes at these conditions (cf Schneider and Eggler 1986). [14]That longer tubes were produced by longer experiments also suggests that tube healing occurred late in the experiment. [15]The tubes appear to heal from their distal ends, ruling out the possibility that they heal behind themselves as they grow. [16]Healing (necking down) of tubes into inclusions is consistent with the experiments of Wanamaker and Evans (1985) on diffusional crack healing in olivine; they noted that 1-6d were required at 1200 12°C to form an isolated inclusion from a tube. [17]These kinetics are orders of magnitude too slow to support healing during the quench. [18]The healing process could be enhanced by a drop in the solubility of olivine in the fluid during decompression, but it is unlikely that such a decrease in solubility could explain the difference between Wanamaker and Evans' (1985) kinetics and those necessary to explain tube healing as a quench phenomenon.

[19]Hacker and Christie (1991) recently showed that altered plagioclase crystals in experimentally deformed amphibolites contain linear defects showing anomalous contrast in the TEM. [20]During electron irradiation, these anomalous regions rapidly become amorphous and transform into tubes. [21]They suppose that these anomalous defects were "silica-water-filled tubes" at the conditions of the experiment. [22]They do not explicitly state whether the anomalous regions represent a quenched silicate melt with dissolved H20 or an H20-rich fluid with dissolved silicate material. [23]From the standpoint of etch tunnel formation the distinction between aqueous melt or silicate-rich fluid may not be significant. [24]The amphibolite is partially molten at the conditions of their experiments, and the altered plagioclase crystals (with vanable and generally more calcic An contents than unaltered crystals) are probably those involved in the generation of melt. [25]Although the dimensions of the tubes they observed in plagioclase are smaller than the etch tunnels in olivine described here, the processes by which they are produced may be quite similar. [26]They consider these tubes to be a previously unrecognised mechanism of chemical transport.

[27]If Hacker and Christie (1991) are correct that dissolution (or melting) of linear defects is a fundamental mechanism by which minerals approach equilibrium, then some of the questions unanswered by this study warrant further investigation. [28]For example, are impurities segregated on growth dislocations in San Carlos olivine, and if so what are they and how do they influence dissolution and melting? [29]Why is etch tunnel formation sensitive to the chemical environment stabilised by the pressure assembly? Most problematic of all, when do etch tunnels stop growing and start healing?

[30]Finally, previous experiments with C-O-H fluids conducted in piston cylinder apparatus utilizing BN in the pressure assemblies probably have produced etch tunnels in minerals. [31]Such fluid-filled tubes likely would have been interpreted as crystal growth phenomena by previous investigators; etch tunnels are observable in the polycrystalline olivine surrounding the single crystals in our experiments. [32]If we had not been using large olivine single crystals, it is not likely that we would have recognized etch tunnels in olivine either.

NS-07: Theoretical studies of the speciation of Al in Fe-bearing aluminosilicates glasses

[1]Having established that our calculations reproduce expected trends in bond distance, NMR shielding electric field gradients, and vibrational spectra, we can use the results to help in assigning the NMR spectra of the F-bearing aluminosilicate glasses.

[2]The assignment of the peak at rF of-193 to AIF (Schaller et al., 1991b) seems reasonable in light of the good match to M3AIF6. [3]The Al NMR spectra has a feature at 3 27AI of 55, assigned to fourfold-coordinated Al, very much like those seen in F-free aluminosilicates. [4]We assign this to Al fourfold-coordinated by bridging O, for which our molecular model would be S3 symmetry Al(OH)4 with Al-O-H increased to some value larger than the equilibrium one of 106.5%. [5]Since replacement of one OH by an F increases the Al NMR shielding by only about 10 ppm, we cannot completely exclude species such as AIF(OH) contributing to the 55-ppm peak, which would be slightly broader on its low f (shielded) side. [6]If we assume, on the basis of the '9F Cramps results, that the feature at f = -1ppm in the Al spectrum represents AIFb, then the experimental difference of about 56 ppm between fourfold- and sixfold-coordinated species is at

least consistent with our results for AlFb vs Al(OH), with a difference of between 33 and 74 ppm, depending upon Al-O-H.

[7]Clearly it would be desirable to perform calculations on larger Al(O-T), clusters to substantiate this. [8]Unfortunately, such ambiguity is difficult to eliminate completely in comparing halides and chalcogenides as ligands.

[9]The species yielding the intermediate slightly deshielded Al NMR peak (f3A' 22 ppm) and the deshielded F NMR peaks (fF -165 ppm) might differ from AlFb by having a lower coordination number, by the substitution of F by O-T or by incorporation in the polymeric network.

[10]The absence of any enhancement in the '9F 29Si CP-MAS spectra compared with the conventional 29Si MAS spectra indicates that there are no direct Si-F interactions. [11]The absence of a peak in the 29Si NMR at the SiF 2-position further supports the conclusion that SiF23- groups are absent, and so these cannot explain the deshielded feature in the '9F NMR.

[12]The calculated Al and F deshieldings of AlF23 compared with AlF3 are only 11 and 18 ppm, respectively, considerably smaller than the experimental peak separations of about 23 and 30 ppm in Al and F NMR, respectively. [13]For the AlF3(0H)2 species, whose calculated structure is shown in Figure 1, the calculated Al deshielding relative to AlF3-is 25 ppm, whereas the deshielding of F is about 29 ppm.

[14]We can calibrate our calculated shieldings by comparing calculated and experimental effects of the coordination number on the 2sSi shielding in various silicon fluondes for which experimental data is available. [15]As shown in Table 8, our calculated (core-corrected) value for the SiF,-SiF23 shielding difference is 64 ppm, whereas the experimental value is 74 ppm (Johannesen et al., 1968). [16]Our previous calculations (Tossell and Lazzeretti 1986), which employed considerably larger basis sets gave a shielding difference (after core correction) of 93 between the fourfold-and sixfold-coordinated species.

[17]On the basis of this comparison with Si shieldings, we expect the present calculations to underestimate the change in Al shielding with coordination number by perhaps a sixth. [18]Even with corrections for this underestimation, it still appears that the shielding difference of AlF 3 and AlF2 is too small to allow assignment of the middle Al NMR peak to a AlF32 species, rather than to the more deshielded AlF,(OH)2.

[19]Incorporation of the AlF302 unit into the aluminosilicate polymer might be modeled by increasing the Al-O-H by a small amount, which would slightly shield Al and probably F as well. [20]Since the Al-O distance in AlFl(OH)22 is quite long (1.870 A), such Al-O-T linkages might have fairly small angles (long T-Ob distances are generally correlated with small <T-O-T). [21]AlF,(OH)2 also has a small EFG, consistent with the Al NMR spectra. [22]Another possibility would be AlF (OH)2, which also has a small EFG, but according to the results in Tables 2 and 3 is probably too deshielded in both Al and F NMR to fit the experimental data. [23]Another species closely related to AlF3(OT)2 would be a species like AlF1(Na)2, with the T-O-T bonds broken to convert bridging to nonbridging O. [24]Distinguishing the degree of tetrahedral polymerization of such a species from NMR would certainly be difficult.

Conclusion

[25]Although calculations using quantum mechanics on even simple gas phase molecules do not exactly match experimental results at the level of rigor used in this paper, and although the molecular models used cannot capture all aspects of the behavior of condensed phase species, we nonetheless feel that semiquantitative estimates of trends in properties can be confidently obtained at this level. [26]On the basis of our results, the five-fold-coordinated Al species identified in the Al NMR spectra of F-bearing aluminosilicate glasses probably has both F and O in its first coordination sphere, a probable molecular model being AlF3(0H) 2, rather than AlF 32, as previously thought. [27]The major Al NMR peaks may still be confidently identified with Al(OH), and AlF species.

NS-08: Calculated frequencies of O-H stretching for different local orderings of Fe and Mg in simple clinoamphiboles

[1]Structural details, generated as the result of DLS analysis, are complicated and not all easily anticipated. [2]Most of the adjustments are subtle and arguably not significant with regard to the objectives of the exercise.

[3]As anticipated, Fe-bearing octahedra modeled in tremolite or cummingtonite are larger than corresponding observed octahedra, such that the model Fe-bearing octahedra more nearly approach geometries in grunerite. [4]Similarly, Mg-bearing octahedra modeled in grunerite or cummingtonite are smaller than corresponding observed octahedra, such that the model Mg-bearing octahedra more nearly approach geometries in tremolite. [5]During the course of DLS analysis, the articulation of the Si-bearing tetrahedra changed slightly, but with practically no change in individual tetrahedral geometries (i.e., practically no change in Si-O and 0-0 distances of tetrahedra).

[6]With regard to the local structural environment of the hydrogen, the most obvious and consistent relationship is between the x coordinate of the O(3) oxygen, xo(3), and number of Fe and Mg atoms coordinated to the hydroxyl oxygen. [7]Figure 2 illustrates this relationship in terms of the distance between the DLS-adjusted 0(3) site and the (100) plane passing through the octahedrally coordinated M cations (at x = 0). [8]Successive substitutions of Fe2 for Mg at the three M2+ sites coordinated to an OH in tremolite increases x03). [9]The same relationship is apparent for the DLS-adjusted structures of cummingtonite and grunerite. [10]In cummingtonite, the DLS-adjusted x013 coordinate for the HO-Mg2Fe ligand composition is nearly the same as the observed x03). [11]This is consistent with the fact that the observed, bulk Fe2/(Mg+Fe2+) in cummingtonite is 0.38, only slightly greater than Fe2+ /(Mg+Fe2)=0.33 for the modeled ratio of Fe/Mg = 1/2. [12]This in turn tends to support the use of values for LOH and POH that are slightly different from those determined for tremolite. [13]For the one ligand composition with a lower Fe/Mg ratio, (0/3)X0/3) is lower than the observed x013). [14]For ligand compositions with higher Fe/Mg ratios (2/1 or 3/o), the DLS-adjusted ratio is proportionately higher. [15]In grunerite, Mg substituting for Fe has the effect of decreasing Xo/30.

[16]Tables 3, 4 and 5 report the results of the QUICKSIT and STRETCH calculations on the DLS-adjusted structures. [17]The calculated coordinates of hydrogen are such that corresponding O-H distances are consistently close (0.01A) to 0.96A which is the observed distance in tremolite.

[18]Thus the calculated position of the hydrogen atom is strongly correlated with the position of the O(3) oxygen, but in such a way that the calculated O-H distance is relatively insensitive to the position of the O(3) oxygen. [19]Whereas the orientation of the OH dipole is implicitly controlled by other atoms in the structure, the O-H distance is not so strongly influenced.

[20]From past experiences (Abbott 1990, 1991), we have learned that calculated frequencies for O-H stretching are extremely sensitive to even the slightest changes in a structure, especially with regard to the position of the hydroxyl oxygen, and ligands other than the hydrogen.

[21]Although not completely satisfactory, we consider the agreement between calculated and observed frequencies of O-H stretching to be quite encouraging. [22]For tremolite, the agreement between the observed and calculated frequencies for the A band is no coincidence, inasmuch as this frequency and the observed O-H distance were the basis for determining the values for the short-range repulsion parameters, OH and POH. [23]The important achievement of the calculations is that the calculated frequencies for the four bands differ from observed frequencies by no more than 4cm-1.

[24]For cummingtonite, the calculated frequency of the A band is close to the calculated (and observed) frequency of this band for tremolite. [25]Calculated frequencies of the B' and C'

bands are respectively 5 and 3cm higher than observed, whereas the calculated frequency of the D band is approximately 15cm lower than observed. [26]Despite the discrepancies, the calculations correctly reproduce the order of the frequencies.

[27]Disagreement between observed and calculated frequencies may be attributable to a slight exaggeration of otherwise qualitatively correct local structural details, or it may be that values for δOH and POH should vary slightly as a function the Fe-Mg composition of the HO-M3 ligands.

[28]Four frequencies of OH-stretching were calculated for grunerite, corresponding to the A, B' C' and D bands. [29]The agreement between calculated and observed frequencies is good only for the D band, for which the local HO-M ligand composition corresponds most closely to the actual composition of the grunerite. [30]The other O-H stretching frequencies are too high by as much as 20cm).

[31]It is perhaps noteworthy that the calculated frequency of the A band (3696cm is reasonably close to observed frequencies of this band for magnesio-hastingsite (3705cm, Semet 1983) and synthetic Mg-rich pargasite (3709cm Raudsepp et al., 1987).

[32]In general, the agreement seems to be best where the Fe/Mg ratio in the local HO-M3 configuration is reasonably close to the observed ratio for the whole structure.

Conclusions

[33]1. For simple amphiboles, DLS-adjusted structures for different arrangements of Mg and Fe at the M(3) and M(1) sites yield calculated O-H stretching frequencies that are reasonably consistent with those observed. [34]Problems in the approach have mostly to do with the prescribed distances used in the DLS analysis, and the precise values for the short-range repulsion parameters, LOH and POH.

[35]2. Values for LOH and POH vary slightly depending on the occupancy of the M(4) sites.

[36]For tremolite, the best values are OH = 30500 kJ/mole of H, and POH = 0.2560 A.

[37]For granite or cummingonite, the best values are OH = 30067kJ/mole of H, and POH = 0.2586 A.

[38]For a given mineral, values for OH and POH may vary slightly as a function of the Fe/Mg ratio in the composition of the HO-M3 ligands.

[39]By all indications, the differences in the frequencies of the A, B, °C and D bands are specifically related to local variations in the structure, especially with regard to the position of the hydroxyl oxygen, O(3). [40]The single most important factor influencing the position of the O(3) oxygen appears to be the ionic radius of the M(1) and M(3) cations.

NS-09: Topaz: Energy calcualtions bearing on the location of Hydrogen

[1]For an H1 hydrogen atom, near an oxygen atom at the F1 site, Table 2 gives the coordinates and energy, WH, at the position of minimum energy for each of the 32 possible orderings of oxygen and fluorine on sites F2, F3, F4, F5 and F6 (Fig 1). [2]The table also gives interatomic distances H1-F3 and, where relevant, H1-H6. [3]The simplest ordering involves fluorine atoms at F2, F3, F4, F5 and F6 (i.e., no OHF, substitution in the local environment surrounding the F1-H1 oxygen-hydrogen pair).

[4]Presumably this situation would pertain to a low ratio OH/(F+OH), where the hydroxyl groups are more or less evenly distributed over the extended structure.

[5]The ordering approximates the local environment of a hydroxyl group in the P1 structure (Parise 1980, Parise et al., 1980).

[6]Figure 2 is a map of the energy, WH, that a hydrogen atom would have at different positions in the (010) plane passing through the F1 oxygen atom. [7]All of the observed positions of hydrogen (Table 1) plot in the small, filled rectangle. [8]The calculated minimum-energy position (ordering #1, Table 2) is marked by the filled circle. [9]The calculated and observed positions are approximately 0.4 A apart. [10]The calculated H1-F1 distance is 0.99 A, which is only slightly longer than the observed distance of 97 A (Parise 1980, in Ribbe 1982). [11]The calculated and observed angles, F1-H1, 115 and 134 respectively, differ by 19.

[12]For purposes of comparison of the effects of different OH-F orderings, this discrepancy between calculated and observed OH orientations is acceptable. [13]The reader should, however, keep in mind that OH dipoles, based on the calculated positions (Table 2) may all be systematically misoriented by as much as 20.

[14]The results reported in Table 2 fall into three groups, which are distinguished on the basis of the calculated energies (Fig 3) and the calculated location of the H1 hydrogen (Fig 4). [15]Group I consists of all OH-F orderings involving +H2 H4 H5 hydrogen atoms (i.e., all orderings with no H3 hydrogen and no H6 hydrogen). [16]This includes the simplest ordering just discussed, ordering 1/1 (Fig 2, Table 2), which is fairly representative of the group. [17]Energies in Group I range from 550 to 675 kJ/mole of H+ (Fig 3). [18]The calculated locations for the H1 hydrogen are reasonably close to the observed positions (Table 1).

[19]The results indicate that any combination of H2, H4 and H5 hydrogen atoms has little influence on the location of the H1 hydrogen, and little influence on the energy.

[20]Group II consists of all orderings involving H6 H2+H4+H5 hydrogen atoms (i.e., orderings with an H6 hydrogen, but no H3 hydrogen). [21]This group includes the simplest violation of the H-H avoidance rule, ordering 6 (Table 2), which is fairly representative of the group.

[22]The distinguishing characteristics of the group-II orderings may be attributed to the effects of repulsion between two closely juxtaposed H1 and H6 hydrogen atoms. [23]The repulsion between H1 and H6 hydrogen atoms causes the corresponding OH dipoles to rotate away from each other, widening the angles a-F1-H1 and a-F6-H6 (Fig 4), thus increasing the H1-H6 distance.

[24]Group-II orderings have the highest energies, from 750 to 850 kJ/mole of H+, which supports the H-H avoidance rule.

[25]With such high energies, group-II local orderings are probably not very important in natural topaz.

[26]Group III includes any ordering involving an H3 hydrogen (i.e., H3 H2 H4 H5+H6 hydrogen atoms). [27]The simplest ordering in the group is 3 in Table 2.

[28]Like Groups I and II, the simplest ordering is fairly representative of the group, and the group characteristics are not influenced significantly by the presence or absence of any combination of H2, H4 and H5 hydrogen atoms.

[29]However, the influence of an H6 hydrogen atom appears not to be so clear as it was in group II, primarily because the group-III energies are by far the lowest, from 400 to 625 kJ/mole of H+ (Fig 3).

[30]Group-III orderings involving an H6 hydrogen have the longest H1-H6 distances, 2.77 to 2.99 A (Table 2), which might be attributed to H-H repulsion, but the angles a-F1-H1 in the group are similarly wide regardless of the presence or absence of an H6 hydrogen (Fig 4). [31]Of more significance in explaining the characteristics of the group are the unusually short H1-F3 distances, from 1.94 to 2.13 Å (Table 2). [32]The shortened H1-F3 distances are attributable to the attraction of the F3 oxygen. [33]Evidently the group-III orderings are stabilized by hydrogen bonding of the sort OF1-HH1...OF3. [34]It should be noted that within group III, orderings involving an H6 hydrogen do have the highest energies, but the energies are still significantly lower than any of the group-II energy levels. [35]Thus the most important feature of group III is the hydrogen bonding, inferred on the basis of the short, calculated OF3...H distances (Table 2).

[36]With their relatively low energies, group-III local orderings could be very important in natural samples of topaz, and provide a possible explanation for the infrared absorption data

(Aines & Rossman 1986), which indicate two kinds of hydrogen sites. [37]In low-symmetry topaz, e.g., in space group P1, excess hydrogen over the amount consistent with an OH/(F+OH) fraction of 1/8 may be accommodated in sites stabilized by hydrogen bonding.

Conclusions

[38]1. Local orderings consistent with group I are neither stabilized by hydrogen bonding, nor destabilized by H-H repulsion. [39]The energies are low, and the calculated positions for the H1 hydrogen are consistent with observed positions. [40]Thus any combination of neighboring H2, H4 and H5 hydrogen atoms has little influence on the energy and position of the H1 hydrogen. [41]For very low fractions of OH/(F+OH), which is the case in most samples of topaz, entropy considerations may dictate that group-I local orderings are more important than group-III local orderings, even though the latter have somewhat lower calculated energies.

[42]2. The H-H avoidance principle (Parise et al., 1980) does not pertain to all local OH-F orderings involving hydrogen atoms related by the (0 0 1) mirror. [43]The principle is relevant only in local orderings that preclude hydrogen bonding of the sort OF-HH1 OF Local orderings subject to the destabilizing influence of H-H repulsion, as in group-II (H6+H2:H4-H5), have high energies and are probably not very important in natural topaz.

[44]3. Hydrogen bonding of the sort OF1-HH1 OF3 in group-III orderings (H3+H2+H4+ H5+ H6) stabilizes the structure regardless of the presence or absence of other hydrogen atoms. [45]Hydrogen sites stabilized by hydrogen bonding may account for infrared absorption data that indicate two kinds of hydrogen sites in topaz.

[46]With regard to hydrogen bonding, it is tempting to consider an extended chain of oxygen atoms substituting for each of the fluorine atoms adjacent to a particular 11 0 0] 21 screw axis. [47]The associated hydrogen atoms would be in symmetrically equivalent local environments like the H1 environment in group-III ordering #7 (-2 charges at F1, F2 and F3 in Table 2). [48]Such a linear defect of hydroxyl groups should be stabilized along its length by hydrogen bonding. [49]By further extension, and by analogy with the synthesis of pure OH-chondrodite (Yamamoto 1977), where a similar problem exists, it may even be possible to synthesize pure OH-topaz at high pressures. [50]This is suggested by the relatively low energy for the group-III ordering involving hydroxyl substituted for all the fluorine atoms (ordering 32 Table 2).

NS-10: Gladstone-Dale constants for the major elements in silicates: coordination number, polarizability, and the Lorentz-Lorentz relation

[1]Na2O: From synthetic Na2Si2O6, 5-coordinated Na yields a GDC of 0.184. [2]Octahedrally coordinated Na in cyclosilicates yields a GDC of 0.179. [3]From pyroxenes, the GDC is 0.162, for amphiboles, 0.127, for layer silicates, 0.098, and for framework silicates, the GDC is 0.155. [4]Jaffe's average value for VIINa2O is 0.178, but it is not clear how this figure was derived. [5]Because GDCs for a compound are additive, some difference in the result for framework silicates is to be expected because of difference in the values found for IVAl2O3 (0.226 for layer silicates, 0.218 for framework silicates).

[6]MgO: Six-fold Mg occurs in olivines and pyroxenes; both data sets yield 0.196. [7]Pyrope has Mg in 8-coordination; a least-squares analysis of 93 garnets with the GDCs for SiO2 and VIAl203 held invariant yields 0.195 for MgO not significantly different from the value for VIMgO. [8]Akermanite has Mg in tetrahedral coordination; the refined GDC for MgO is 0.222, somewhat lower than Jaffe's figure of 0.239 for melilite.

[9]Al2O3: Al in six-fold coordination to oxygen occurs as a major component in kyanite, topaz, and staurolite among orthosilicates, and in the pyroxenes jadeite, aegirine, and spodumene. [10]Both mineral groups yield a GDC for Al2O3 of 0 188 by least-squares analysis. [11]Al in four-fold coordination occurs in framework silicates, in cordierite and the osumilite group, and in sillimanite. [12]For the feldspar data-set of Gumer & Bloss (1982), the least-squares method will give equally good results for any GDC for Al203 within reasonable limits because the values for Ca and Na simply adjust to lit the observed indices, and consequently these data cannot define a value for VAl2O3. [13]A data-set of 65 framework silicates samples yielded a GDC of 0.218 for IVAl2O3. [14]The cordierite-osunilite data and sillimanite (two samples) yield 0.226 for IVAl2O3, and andalusite samples yield 0.212 for VAl2O3 with VIAl2O3 = 0.188. [15]These values for Al2O3 were used in all other group refinements, and are similar to Jaffe's.

[16]CaO: From shannonite, larnite, rankinite, and wollastonite, a GDC of 0.222 was derived for v CaO. [17]In pyroxenes and amphiboles, Ca has six nearest neighbors, and two are somewhat further away; the GDCs are 0.218 and 0.211 respectively. [18]In layer silicates, Ca lies in the interlayer space and has six nearest neighbors, and two further away the GDC is 0.203. [19]Framework silicates have Ca in relatively large cavities with a high coordination number (8, commonly); the GDC for CaO in framework silicates is 0.207. [20]From grossular, the GDC for VIICaO is 0.205. [21]The differences in GDC for CaO may be attributed to differences in coordination number. [22]The lower value obtained from amphiboles than from pyroxenes may reflect the more layer-like structure of the amphiboles.

[23]FeO: Many silicates contain octahedrally coordinated Fe2+: the average GDC from orthosilicates pyroxenes, and layer silicates is 0.187. [24]The value derived from amphibole is lower, 0.180, the same as the value found in garnets (0.180), in which Fe2+ is in 8-coordination. [25]In melilites and epidotes, Fe2+ is in tetrahedral coordination, and these minerals yield a GDC for FeO of 0.199.

[26]MnO: A GDC of 0.188 for VIMnO was derived from orthosilicates and pyroxenes for the 8-fold site. [27]In garnet, the GDC is 0.176.

[28]TiO2: Ti in garnet largely substitutes for Si in tetrahedrally coordinated sites (Huggins et al., 1977), whereas in pyroxenes and orthosilicates, it is in 6-fold coordination. [29]There is also some question regarding the valence of Ti in silicates, although in the NaTi-pyroxene, Ti is clearly trivalent, and in titanite it is tetravalent. [30]The GDCs for TiO2 vary from 0.465 in garnets to 0.353 in orthosilicates (a value dominated by titanite), and 0.294 in pyroxenes. [31]The variation probably reflect changes in valence and coordination number.

[32]Li2O and BeO: GDCs for these oxides vary widely with mineral group, as can be seen from Table 1. [33]The reason does not appear to be coordination number, as the extreme values are from silicates with Li in octahedral coordination, the intermediate value from tetrahedrally coordinated Li. [34]The GDC for BeO ranges from 0.236 in phenacite to 0.307 in beryl, with no change in coordination number.

[35]Mn2O3: Trivalent manganese occurs in few silicates; the best known are kanonaite and piemontite; these yield a GDC of 0.267. [36]Henriter-mierite garnet gives a GDC of 0.270. [37]The new NaMn-bearing pyroxene described by Lucchetti et al., (1988) and Basso et al., (1989) also contains Mn3+; the data for this sample give a GDC of 0.260. [38]The new mica norrishite (Eggleton & Ashley 1989) gives a GDC for Mn203 of 0.254 Jaffe's figure of 0.259 is said to be applicable to epidote. [39]Until more data become available for Mn3+ bearing silicates, an average figure of 0.265 would seem to be the most appropriate.

Discussion of the silicate groups:

[40]Except for Na2O and CaO, the GDCs listed in the "average" column of Table 1 are applicable to all the major groups of silicates, provided the coordination number of the cations B taken into account. [41]Some structures have cations spread over more than one site, and consequently yield an average GDC. [42]Amphiboles show this effect most markedly; the relatively large M(4) site has some similarity to the interlayer site in a layer silicate, and consequently the GDCs for CaO and FeO are significantly lower than in other structures in which Ca and Fe are octahedrally coordinated. [43]The

GDC for Na2O decreases from pyroxenes to layer silicates, possibly a result of an increasing number of second-nearest neighbors. [44]However, much of the variation is not significant; the standard deviations for Na2O are higher than for most other oxides and holding the GDC for Na2O constant during refinement of the other GDCs gives little increase In the sum of the squares of the residuals.

[45]Some of the variation may be consequence of the distribution of Na over the M(4) and A sites in amphiboles, but the data are not of sufficient quality to assess this hypothesis. [46]CaO shows a similar variation with extent of Si-O polymerization. [47]Excluding garnets, the GDC for CaO varies from 0.221 in orthosilicates, to 0.218 in pyroxenes, 0.211 in amphiboles, 0.203 in layer silicates and 0.207 in framework silicates. [48]This variation correlates well with the coordination number for Ca from orthosilicates to framework silicates (Table 2).

[49]The L-L law has a theoretical basis; it is expressed, following Lasaga & Cygan (1982), as i = 3V(n2-1)/4(n2+2), where i is the polarizability of the ith atom in a molecule, V is the molecular volume (the molar volume in A3 divided by Avogadro's number, or the unit-cell volume/Z where Z is the number of formula units in the cell), and n is the mean index of refraction. [50]The units of i are thus the same as those of V, A3 in this case. [51]Some authors express i in cm3, using the molar volume for V. [52]Numerically, the two usages are related by N/1024, or 0.6022.

[53]Anderson (1975) developed the L-L law to include the effects of electron overlap, significant where covalent bonding is important, as it is in silicates. [54]Anderson's equation (17) can be expressed as [...] where b = 4/3-c. [55]In this equation, 4/3 is the Lorentz factor and accounts for the spherically symmetrical field around a molecule, and c is an electron-overlap factor. [56]Anderson pointed out that if c is equal to zero, (1) yields the L-L relation, appropriate to ionic crystals. [57]Where electron overlap is significant, as in covalent bonding, b may be zero (if c = 4/3), yielding the Drude relation, V(n2-1)4 = i.

[58]If the electron-overlap term c (incorporated in the term b of equation (1) is not zero, the denominator of equation (1) varies; in particular, where equals 2.26 (found by trial and error), the denominator of (1) becomes very close to 6 (n+1) for 1.4 n 1.8, the range of n for silicates. [59]That is, where c equals 2.26, the left side of equation (1) becomes (n+1)(n-1) / 6(n+ 1) = (n-1)/6 (see Table 3).

[60]The G-D relation is (n-1)/d = wigi. [61]If wi is replaced by pi.mi/M, where pi is the number of moles of the ith oxide, mi the molecular weight of the ith oxide, and M the molecular weight of the mineral, and if d is replaced by mass/V, where mass (= M/N) is the unit-cell mass and V the cell volume then the G-D relation can be recast in a form similar to equation (2): (n- 1)VN/M = pimigi/M.

[62]Thus the polarizability is simply related to the G-D constants, and is directly proportional to the index of refraction where c equals 2.26. [63]This result suggests a reason for the success of the G-D relation. [64]By chance (?), it fits the theoretical relation if covalent bonding is significant. [65]Other values of c do not match the G-D relation as well over the range in index of refraction of minerals (see Table 3) and require a factor different from 6. [66]Jaffe (1988) listed the polarizability of a number of minerals using the G-D relation, and assumed that the Lorentz factor 4/3 was appropriate. [67]As the derivation from Anderson's equation shows, the G-D relation requires a factor of about 6; thus Jaffe's figures for polarizability are larger than those indicated here by about 1.5.

[68]The simple oxides MgO, CaO, Al2O3 and TiO2 themselves yield significantly different polarizabilities from those found for these oxides in silicates (Table 4). [69]Use of a smaller value for c in equation (1) brings these polarizabilities into conformity, and so implies a more ionic bond for the simple oxides. [70]For this argument to have any significance, it must be assumed that the Gladstone-Dale relation is valid for structures with the degree of electron overlap found in silicates and therefore that the oxide polarizabilities derived from its use are correct for all oxide structures. [71]Compounds with a degree of ionicity different from that in silicates can therefore have their ionicity assessed by determining b from the indices of refraction and molar volume using equation (1).

[72]An important property of oxide polarizability is that of additivity (Lasaga & Cygan 1982). [73]Table 5 demonstrates the consistency between molecular polarizability for complex silicates derived by summation of oxide polarizabilities and that determined directly from index of refraction using equation (2). [74]The summation for Table 5 uses polarizabilities derived from the average GDCs listed in Table 1, not those that best fit each silicate group

[75]Consideration of electron overlap may also explain why the GDCs for Li and Be are inconsistent. [76]The bonds in silicates are generally held to be about 50% ionic, and the value for t in equation (1) of 2.26 is about half-way between zero and its maximum value of 4/3. [77]Possibly 4-coordinated Li and Be introduce differing extents of covalency in the bonding, resulting in less close adherence to the G-D equation.

Summary

[78]The Gladstone-Dale constants for oxides in silicates are dependent on coordination number; the GDC for an oxide decreases with increasing coordination number. [79]Gladstone-Dale constants calculated separately for garnets, other orthosilicates, pyroxenes, amphiboles, layer silicates and framework silicates do not show significant variation among three major silicate groups, with the exception that the range in site size and coordination in amphiboles causes averaging of the GDC for the larger cations (CaO, FeO). [80]Values determined for the trivalent and tetravalent transition metals show more inconsistency among groups than do most other oxides, possibly because of uncertainty in coordination number, possibly from error in determination of indices of refraction because of intense color. [81]The G-D equation is consistent with Lorentz-Lorent theory if silicates are regarded as having intermediate bond (50% ionic, 50% covalent). [82]The new GDCs for silicates bring 93% of 574 sets of mineral data into Mandarino's "superior" category.

NS-11: Ammonium in zeolitized tuffs of the Karlovassi Basin, Samos, Greece

[1]The possible sources of ammonium in tuffaceos rocks such as those in Samos are as follows: (1) primary ammonium of magmatic origin, or (2) secondary ammonium, introduced during deposition, diagenesis or weathering.

[2]The amount of ammonium that may have been present in the magma originally cannot be known. [3]On the basis of the amount of ammonium in granites, which is typically in the order of 10-100 ppm (Urano 1971, Hall 1988), the rhyolitic parent magmas of the Samos tuffs would undoubtedly have been ammonium-bearing, but all ammonium compounds are unstable at magmatic temperatures under the pressure and ammonium fugacity of the atmosphere, and all magmatic ammonium would have been lost on eruption. [4]This point needs to be emphasized, because there are published results of analyses showing more than 10 ppm ammoniacal nitrogen in some volcanic rocks (compilation of Wlotzka 1972). [5]Such data need to be questioned, because (a) the existing analytical data commonly show chemically combined nitrogen (i.e., including the ammonium ion) exceeding total nitrogen (as measured by vacuum degassing), which cannot be correct, and (b) most existing analytical data do not distinguish between fixed and exchangeable ammonium, the latter being present in significant amounts in almost all rocks that have undergone even a small degree of surface weathering. [6]Unpublished data by one of the authors (AH) on seven very fresh samples of volcanic rocks ranging from rhyolite to basalt showed fixed ammonium to be below the limit of detection (-3 ppm) in every sample; on that basis, fresh volcanic rocks probably do not contain ammonium. [7]All the ammonium found in the Samos rocks is thus taken to be of secondary origin.

[8]There are many possible sources of secondary ammonium. [9]A small amount of ammonium is present in all surface waters and sediments, and is a product of biological activity. [10]Ammonium could have been introduced into the tuffs at the time of deposition from the lake waters, from sediments

in the lake, or by addition of water to the lake, especially if fed by hot springs tapping ammonium from rocks of the surrounding area. [11]Ammonium could have been incorporated during the recrystallization that gave rise to the assemblages of authigenic minerals, or by interaction with groundwater up to the present day. [12]Whatever the source of the ammonium, its incorporation in the rocks is governed by its large ionic size. [13]Because potassium is the only major element for which it can easily substitute, the only rock-forming minerals that carry ammonium are those that also can contain potassium, i.e., feldspars, micas and zeolites. [14]Micas are not significant constituents of the Samos tuffs and the distribution of ammonium in thee rocks was therefore determined by the crystallization of K-feldspar and zeolites. [15]These minerals differ greatly in their ammonium-bearing capabilities. [16]The ammonium ion can be taken up by eolites by cation exchange for Na, K or Ca, but is just as easily displaced by those elements, so that during a long period of geological time, the ammonium content of the zeolites can rise and fall with changes in the composition of ambient hydrothermal solutions or groundwater. [17]In contrast, any ammonium entering K-feldspar is fixed, and is not subject to removal by cation exchange unless the feldspar is replaced by another mineral.

[18]The time scale of diagenetic recrystallization in the Karlovassi tuffs is still largely unknown, but on the basis of the above considerations, a sequence of events that could account for the present distribution of ammonium is:

(1) Deposition of ammonium-free volcanic detritus in a lake basin. (2) Early diagenetic recrystallization of fine-grained volcanic glassy material to give zeolites, by saline-alkaline solutions containing ammonium. (3) Later diagenetic conversion of ammonium-bearing zeolites to ammonium- and boron-rich K-feldspar by highly saline-alkaline solutions. (4) Partial removal of ammonium from the zeolites surviving from stage (3) by groundwater low in ammonium but higher in other dissolved cations.

[19]This sequence should be regarded only as a simple working hypothesis until more is known of the timing of diagenetic events. [20]Whereas the K-feldspar probably crystallized during a restricted time interval when diagenetic waters were at their hottest, the zeolites were subject not only to cation exchange, but also to continuing recrystallization over a much longer period, perhaps extending up to the present day.

NS-12: The timing of alkali metasomatism in paleosols

[1]The Rb-Sr systematics of the Mt. Roe #1 paleosol indicate that the enrichment of K and Rb in the upper part of the profile, and probably the mild enrichment of Ca and Sr, occurred well after weathering took place. [2]The initial 87Sr/86Sr value (87Sr/86Sri) of this suite of samples, 0.70471 O.00003 reflects equilibration of the metasomatizing fluid mainly with the host basalt, and not with older continental material having a high time-integrated Rb/Sr value.

[3]One of the seven samples analyzed was not completely reset during alkali metasomatism, probably owing to its high concentration of Sr. [4]The relatively high 87Sr/86Sr and low 87Rb/86Sr values of this sample require heterogeneity of 87Sr/86Sri in the basalt flows at the time of their emplacement. [5]The observation that the Rb-Sr age of the sericite-rich samples from the paleoweathering zone is the same as that of the stratigraphically higher and lower unweathered basalt suggests that the metasomatic event recorded in the paleosol samples is the same event that produced the chloritization and silicification of the Fortescue Group basalts throughout the Pilbara craton.

[6]The time of alkali metasomatism of samples from the Mt. Roe #1 paleosol postdates weathering by at least 530 Ma, and lies within the range of the observed Rb-Sr ages of 2,700-2,000 Ma for whole-rock samples of Fortescue Group basalts summarized by Blake & McNaughton (1984). [7]Recent whole-rock Rb-Sr data on samples of the Mt. Roe Basalt from a drill core located southwest of the town of Tom Price (Nelson et al., 1990) yield a scattered isochron corresponding to an age of 2,115 447 Ma, and having 87Sr/86Sri = 0.7061 0.0006. [8]A Sm-Nd isochron reported for riebeckite from the Hamersley banded iron formation (BIF) shows that the amphibole grew 2,120 32 Ma ago (Alibert & McCulloch 1990). [9]The similarity of the Sm-Nd ages of secondary riebeckite and the Rb Sr age of the Mt. Roe #1 paleosol suggests that they both reflect a period of low-grade regional metamorphism and metasomatism of the Hamersley and Fortescue groups, which only partly reset the Rb-Sr systematics of unweathered basalts.

[10]The Rb-Sr systematics of samples from the Daspoort Tunnel locality also reflect resetting significantly after the time of weathering. [11]The weathering profile is thought to have formed approximately 2,200 Ma (Holland & Beukes 1990, and references therein); the Rb-Sr data indicate an age of 1,925 32 Ma. [12]The Rb-Sr age corresponds to the emplacement of the upper granitic members of the Bushveld Complex; the Nebo Granite of the Lebowa Granite Suite is dated at 1,920 + 40 Ma by the U-Pb (zircon) method (Coertze et al., 1978). [13]The alkali metasomatism in the Daspoort Tunnel profile probably occurred in response to hydrothermal activity generated by intrusion of the Bushveld Complex, rather than by a regional metamorphic event. [14]Unlike the unweathered Mt. Roe #1 basalt, the sample of unweathered Hekpoort Basalt follow below the isochron defined by the sample of the weathering profile; its Rb-Sr systematics were probably reset slightly by alkali metasomatism (inset of Fig 2). [15]An approximate 87Sr/86Sri value of 0.707 is indicated for the unweathered basalt sample if its Rb-Sr system remained undisturbed after extrusion of the lava.

[16]The 87Sr/86Sri of the paleosol samples of the Daspoort Tunnel profile is quite radiogenic: 0.718 0.003. [17]The metasomatizing fluids must have contatned strontium leached from old crustal materials. [18]The most likely source of the strontium is the Dwaal Heuvel Sandstone that overlies the paleosol. [19]The alteration of potassic feldspar in the sandstone could have contributed radiogenetic Sr as well as abundant K and Rb.

[20]The samples from the weathering plofile developed on the Ongeluk Basalt have more complicated Rb-Sr sytematics than those of the two profiles discussed above. [21]Three samples from the weathering zone have high 87Rb/86Sr values and define an isochron with an age of 1,257 11 Ma. [22]This age is identical within the analytical error with a 1,270 30 Ma Pb-Pb age for the nearby Kameel mafic intrusive body (Dixon 1988). [23]The alkali metasomatism of the paleosol probably accompanied hydrothermal activity associated with the emplacement of this intrusive body. [24]Field evidence for hydrothermal modification of the paleosol was noted by Wiggering & Beukes (1990). [25]Samples having lower 87Rb/86Sr do not conform to the isochron defined by the high 87Rb/86Sr samples, and appear to have been variably reset by the metasomatic event. [26]Sample 733.00, the lowest sample and the freshest basalt in the Ongeluk profile, lies furthest from the isochron, whereas sample 725.48 is much closer to the isochron.

[27]Like the paleosol from the Daspoort Tunnel profile, the Rb-Sr systematics of the paleosol developed on the Ongeluk Basalt appear to have been reset by hydrothermal fluids that circulated in response to magmatic activity. [28]Samples from the most intensely weathered part of the palaeosol had their Rb-Sr systematics completely reset, whereas less intensely weathered and unaltered basalts were only partly reset, which suggests that fluid flow did not penetrate deeply below the paleosol Olifantshoek contact. [29]The high 87Sr/86Sri of the Ongeluk paleosol samples (0.734) indicates that the Sr in the metasomatizing fluids was derived from older, high Rb/Sr material. [30]The sediments in the overlying Olifantshoek Group are a likely source of this Sr.

Conclusions

The Rb-Sr systematics: [31]Three Precambrian paleosols of differing ages from Australia and South Africa reflect resetting and alkali metasomatism well after the weathering events that produced the paleosols. [32]In the case of the Mt. Roe #1 paleosol, the metasomatism appears to have been related to regional metamorphism and metasomatism in the Pilbara Craton. [33]The Rb-Sr systematics of samples from the sericite zone of the Mt. Roe #1 and from the overlying and underlying basalts have all been reset to a common age; this resetting suggests that fluid infiltration and metasomatism were pervasive. [34]The Rb-Sr systematics of samples from paleoweathering profiles developed on the Ongeluk and Hekpoort basalts appear to have been reset by hydrothermal fluids related to nearby igneous intrusive bodies. [35]In these profiles, the Rb-Sr systematics in samples from the highly weathered parts of the paleosols were completely reset; samples of unweathered and lightly weathered basalt were reset slightly, if at all. [36]The incomplete resetting of the unweathered basalts in the Daspoort and Ongeluk profiles reflects limited hydrothermal flow below the unconformities. [37]The Rb-Sr data indicate that the Sr isotope ratios in the metasomatizing fluids of all three paleosols were homogeneous, and that the Rb-Sr systematics of the paleosols have remained undisturbed either by later circulation of fluid or modern weathering.

NS-13: Mineralogy of rare-earth-bearing "thucholite", Parry Sound, Ontarion

[1]As noted above, the spatial relationship of the thucholite to "oil shows" strongly suggests that the thucholite is a pyrobitumen derived from petroleum fluids. [2]The thucholite therefore postdates the pegmatite. [3]The common association with cyrtolite and allanite, the restriction of thucholite to uraninite-bearing portions of the pegmatite, and the occurrence of thucholite coatings around uraninite cores, strongly suggest that the pyrobitumen was localized by radiation from radioactive minerals. [4]This is a common phenomenon and is responsible for the occurrence of thucholite in pegmatites worldwide (Davidson & Bowie 1951, Boyle 1982).

[5]Radiation causes polymerization and condensation reactions in fluid hydrocarbons, which result in the precipitation of solid pyrobitumens (for a detailed discussion of this process, see Schidlowski 1975, Curiale et al., 198). [6]A characteristic feature of thucholite is its property of replacing other minerals, including silicates (e.g., Abdel-Gawad & Kerr 1961, Parnell & Eakin 1987). [7]Uraninite and zircon crystals that have acted as a nucleus for thucholite precipitation generally exhibit irregular outlines owing to marginal replacement (e.g., Welin 1964, McKirdy & Kantsler 1980). [8]The replacement process causes mobility of elements in the replaced minerals. [9]In the Besner thucholite the ellipsoidal crystals and the cross-cutting veinlets are clearly authigenic precipitates rather than relics of a partial replacement process. [10]These two phases probably represent the mobilization and precipitation of elements from the host pegmatite. [11]The irregular masses do not appear to be authigenic and may be a primary mineral of the pegmatite or an Iteration product of a mineral in situ. [12]The occurrence of thucholite within feldspar, mica and quartz, and crystals embedded in thucholite (see above), suggests that the thucholite replaced inorganic minerals.

[13]The major elements recorded in the inclusions of the thucholite would be expected to occur enriched in the minerals of the pegmatite, including monazite. [14]The allanite with which the thucholite is closely associated would be a ready source for the Ca, Th, Ce and La in the thucholite. [15]The large amount of P in the inclusions necessitates mobilization from phosphatic minerals in addition to silicates. [16]Indeed, as all the REE-hearing inclusions recorded in this study are phosphates, phosphates must have been dissolved to facilitate their reprecipitation. [17]However, phosphate minerals have not been reported from the pegmatite.

[18]Low Si and V contents are recorded in each type of inclusion, and probably substitute for P [19]Similarly, Th, U and Ca substitute for the REE. [20]The substitution of Th or U for REE creates a problem of charge balance, which would be accommodated by concomitant substitution of Ca for REE or substitution of Si for P (or both). [21]Total metal/P + V + Si ratios are in the range 0.90 to 1.11 (Table 2). [22]The stoichiometric balance between metals and anionic elements indicates that the ideal formula MPO4 is generally upheld. [23]However, the direct measurement of Oxygen contents shows that oxygen is present in excess of the levels expected according to stoichiometry. [24]Assuming that no (OH) ions are present, the excess oxygen is probably present as water molecules. [25]An abnormal degree of damage sustained by the inclusions under the electron beam could be explained by the dehydration of a hydrated phase. [26]The most likely hydrated phosphate phase would be rhabdophane whose formula includes a single water molecule consistent with oxygen/metal atomic ratios between 4 and 5 found in two of the three phases (Table 2). [27]These two phases are distinguished by high enrichments in either La or Ce, and rhabdophane is recorded elsewhere as both La-rich and Ce-rich varieties (Hildebrand et al., 1957, Van Wambeke 1977). [28]Variations in Ce content have been explained as due to the partial fractionation of REE following oxidation of Ce3+ to Ce'+ ions at some stage preceding rhabdophane precipitation (Adams 1968). [29]Rhabdophane described by Hildebrand et al., (1957) contains Pr, Sm, Eu, Gd, Dy, Er and Yb at oxide concentrations over 0.5%, but none of these elements was detected in the phases analyzed in this study and, if present, must occur at concentrations less than 0.05%. [30]The high Th content in the third phase suggests affinities with brockite. [31]However, the brockite described by Fisher & Meyrowitz (1962) contains an excess of Nd over Ce, La and Y, opposite to the trend recorded in this phase. [32]The phase contains a greater excess of oxygen than the other two and may be more hydrated. [33]Several Y and REE phosphates are known with multiple hydration, including churchite (Y,REE)PO4.2H2O, lermontovite (Ca,U, REE)3 (PO4)4.6H2O, ningyoite (Ca,U,Ce) PO4.nH20, and an unnamed phase (Y,U,Ca) PO4.6H20 (Parnell 1989). [34]The oxygen/metal atomic ratios close to 6 suggest a formula with two water molecules, similar to churchite.

[35]Of the two authigenic phases, the low-(Ce/La) ellipsoids appear to postdate the high-(Ce/La) veinlets. [36]Few data are available elsewhere for the paragenesis of rare-earth phosphate phases. [37]Van Wambeke (1977) reported the precipitation of Ce-rich rhabdophane before La-rich rahbdophane, and an account by Read et al., (1987) of zoned authigenic monazite shows that Ce-rich monazite precipitated before La-rich monazite. [38]In both cases, the sequence is the same as that in the thucholite. [39]A possible explanation suggested by Read et al., (1987) is the slightly greater solubility of LaPO4 than CePO4 (see data in Kolthoff et al., 1969), which would cause an earlier precipitated phase to be relatively Ce-rich. [40]Similarly, Murata er al., (1953) predicted from solubility trends (at that time theoretical) that if two generations of monazite were found in a single deposit, the later phase would be richer in La.

[41]It is likely that the mobilization-reprecipitation process occurred on a very localized scale. [42]This would explain the fact that at the same locality, different varieties of thucholite can be distinguished which are rich in U, Th, or the Ce group of rare earths. [43]The varieties represent alteration of different primary minerals. [44]In the case of the RE-rich thucholite, the alteration of allanite to chlorite would have released the metals that formed the monazite inclusions.

NS-14: A gahnite-garnet retrograde reaction from the Pinnacles deposit, Broken Hill, New South Wales, Australia

[1]P-T fields of stability for hercynite, the ferroan spinel end-member, have been calculated according to the prograde reactions (Wall & England 1979). [2]The equilibria indicate that hercynite-quartz is a high-temperature (750C), medium- to high-pressure (2-8 kbar) assemblage, characteristic of granulite-facies terranes (Bohlen et al., 1986). [3]The presence of Zn in the crystal structure is considered to increase the field of stability of the spinel into the amphibolite-facies domain (Frost 1973, Dietvorst 1980, Montel et al., 1986). [4]The mineral assemblage observed (quartz-garnet-gahnite with minor biotite) is simple, which suggests either 1) completion of the metamorphic reactions above with the removal of cordierite or sillimanite (or both), or 2) a different reaction that does not involve an aluminosilicate.

[5]Cordierite is not observed in other garnet-bearing pelites at the Pinnacles mine; Mg-bearing pyroxene, also a metamorphic product in the sillimanite-spinel-cordierite- garnet-orthopyroene system (with excess quartz) for pelitic rocks (Vielzeuf 1983), is rare in these rocks, suggesting that neither of these two phases were present prior to the occurrence of these reactions. [6]Sillimanite, on the other hand, is a common constituent in many pelites within the mine sequence, although it is nearly always retrograded to muscovite, which is consistent with hydration during retrograde metamorphism (Corbett & Phillips 1981). [7]It is possible, therefore, that the observed texture of garnet corona around gahnite crystal in a quartz matrix, with only minor biotite and apatite, represents the incomplete prograde reaction of Wall & England (1979) (reaction 2) after the removal of sillimanite. [8]However, evidence such as the sharp contacts between corona and core, the lack of muscovite in this rock, the minor occurrence of retrograde biotite associated only with prograde garnet, and the similar chemistries of garnet coronas to both gahnite and garnet crystals, indicates that this reaction is a retrograde one that induced the formation of garnet during the breakdown of gahnite.

[9]The formation of garnet as a product of the breakdown of hercynite during retrograde metamorphism is predicted (e.g., Vielzeuf 1983) but not widely documented in the literature. [10]Muscovite is the more commonly observed product of retrograde metamorphism in gahnite-bearing pelites: it is observed elsewhere in the mine sequence and is widely reported for the Willyama Super- group (e.g., Barnes et al., 1983). [11]In many of the gahnite-bearing, garnet-rich pelitic assemblages of the Pinnacles Mine Sequence, garnet crystals are subhedral, with an inclusion-rich core and an inclusion-free corona, similar to the gahnite crystals described above. [12]In these rocks, both garnet coronas and garnet cores are partially resorbed along the S2 foliation, which suggests a pre-S2 crystallization. [13]Both cores and rims have the same almandine chemistry (Table 2) as do the garnet coronas to the gahnite crystals described above which suggests that garnet grains and garnet coronas formed in close succession and, therefore, both represent metamorphic events during S2.

[14]The lack of muscovite and sillimanite in association with the quartz-garnet-gahnite (minor biotite and apatite) assemblage described here could be interpreted as a result of a gahnite- garnet reaction, representing destabilization during retrograde metamorphism of a quartz- gahnite assemblage in an anhydrous environment. [15]A retrograde reaction in an anhydrous environment would, however, be unusual, especially as evidence for fluid migration is common elsewhere in the sequence (e.g., in late-stage shear zones). [16]Alternatively, the assemblage may represent a reaction in the absence of significant amounts of Al. [17]The reaction involving the observed phases must include the addition of Fe with minor amounts of Mn, Mg, Ca and Na, and the removal of Zn. [18]Therefore, the retrograde metamorphism took place in the presence of Fe-and Si-rich fluids that contained minor concentrations of Mn, Mg, Ca, and Na, but involved the removal of Zn away from the immediate assemblage. [19]Possible "sinks" for the mobile Zn include staurolite, biotite and sphalerite. [20]Stoddard (1979) observed the prograde formation of gahnite from staurolite in granulite-facies metapelites and amphibolite-facies cordierite-amphibole rocks from North America; in the Pinnacles Mine Sequence, the reverse appears to be true. [21]Staurolite is observed in several specimens of pelitic schists, but not in those exhibiting the gahnite-garnet reaction. [22]The staurolite is Zn-enriched (up to 4.2 wt. ZnO) and forms pseudomorphs of gahnite crystals; therefore staurolite probably formed by the retrograde breakdown of prograde gahnite. [23]Biotite is a common retrograde product of the Fe-rich spinel hercynite in hydrous conditions (Montel et al., 1986). [24]In the Pinnacles Mine Sequence, retrograde biotite contains only trace amounts of Zn (0.6 wt,7, ZnO detected in one microprobe analysis), suggesting that Zn was not preferentially hosted in this mica. [25]Sphalerite, however, is common in rocks of the mine sequence, although not in the immediate vicinity of the retrograde textures described here. [26]Consequently, the Zn seems to have been transported by hydrothermal fluids associated with retrograde metamorphism and was deposited in sulfur-rich reducing environments as sphalerite. [27]Kyanite- and staurolite-bearing late-stage shear zones in the Pinnacles area (the Thackaringa-Pinnacles Shear Zone; Stevens 1986) indicate that high-pressure conditions were maintained during the late-stage metamorphic event that caused the formation of a garnet rim on gahnite grains a described in this paper. [28]The reaction of Wall & England (1979) (reaction 2), which has a steep positive gradient on a P-T diagram (Bohlen et al., 1986), also is observed in the micaceous schist within the mine sequence. [29]The transition from gahnite to garnet in the absence of sillimanite is thermodynamically unconstrained, but it seems o represent conditions in which temperature decreased more rapidly than pressure (cf petrogenetic grids for sillimanite-bearing rocks of Bohlen et al., 1986 and Montel et al., 1986). [30]All these factors support an isobaric retrograde event. [31]Such an interpretation is consistent with regional P-l calculations that suggest an anticlockwise P-T-t path with final isobaric cooling (Corbett & Phillips 1981, Phillips & Wall 1981).

NS-15: Structural state of the K-feldspar in the Butler Hill-Breadtray Granite, St. Francois Mountains, Southeastern Missuri

[1]If the model of Sides (1980) for the geometry and emplacement history of the Butler Hill Breadtray pluton is correct, the depth of crystallization for our samples ranges from approximately 1 to 2 km in the southwest to approximately 10 km in the northeast. [2]Regardless of what factors are the most important in controlling the structural state of K-feldspar in a large plutonic body, one would expect K-feldspar formed under such disparate conditions to show a significant amount of structural variation. [3]However, the total range in degree of order shown by our samples is actually quite small. [4]Furthermore, the trend surfaces that best fit our data on structural state coincide much more closely with the present-day erosion surface than with the trend surface that best fits the major-element chemical data of Sides (1980). [5]Therefore, we must conclude either 1) that the tilted-batholith model is incorrect, or 2) that the structural state of the K-feldspar in the presently exposed parts of the Butler Hill-Breadtray granite reflects postcrystallization ordering in an event that operated along a nearly horizontal surface subsequent to any tilting that may have occurred. [6]Independent petrographic and geochemical evidence strongly favors the latter interpretation.

[7]The first detailed petrographic study of the rocks exposed in the St. Francois Mountains was published by Tolman & Robertson (1969). [8]Sides (1978) studied the Butler Hill-Breadtray granite in detail, both geochemically and petrologically; a summary of his findings was published by Sides et al., (1981). [9]Lowell (1976) reported petrographic details for the plutonic rocks exposed in Hawn State Park, the exposure that we, following Pratt et al., (1979), refer to as the northeastern outlier of the Butler Hill granite. [10]All of these studies reported evidence of postcrystallization alteration, both in the feldspars and in the ferromagnesian minerals.

[11]Sides et al., (1981) claimed that the extent of alteration increases from northeast to southwest across the Butler Hill-Breadtray pluton, but our petrographic examination of the samples used in this study does not support that conclusion. [12]With the exception of the two samples from the northeastern outlier, which show only minor to moderate alteration, all our samples show evidence of pervasive alteration. [13]Virtually all of the feldspar crystals, both K-feldspar and plagioclase, are extensively clouded by a fine-grained aggregate of kaolinite or sericite plus hematite. [14]Many of the K-feldspar crystals show the "less regular" or "patchy" perthitic texture indicative of recrystallization or albitization (Hatch et al., 1972). [15]The primary ferromagnesian minerals, mostly biotite with subordinate hornblende, are extensively altered to chlorite + epidote + opaque phase (magnetite?) + hematite + titanite + rutile. [16]The pervasiveness of the secondary hematite accounts for the characteristic "brick red" color of this rock unit on outcrop. [17]Tolman & Robertson (1969) attributed the extensive alteration in the Butler Hill-Breadtray granite to deuteric processes operating immediately after crystallization, but recent geochemical data suggest that at least a significant fraction of the alteration

may have been caused by a much more recent hydrothermal event. [18]Rb-Sr dates for many rocks exposed in the St. Francois Mountains are significantly younger (1290-1380 Ma) than the corresponding U-Pb zircon dates (1460-1480 Ma) (Bickford & Mose 1975, Bickford et al., 1981). [19]Bickford & Mose (1975) interpreted these anomalously young Rb-Sr dates to represent loss of Sr during a period of extensive hydrothermal alteration that occurred at some time subsequent to 1300 Ma. [20]The oxygen and hydrogen isotope data of Wenner & Taylor (1976) also indicate a late Precambrian hydrothermal event in the St. Francois Mountains. [21]Wenner (1988) concluded that this postcrystal-lization event affected rocks to a depth of at least 3 km. [22]It seems quite reasonable that K-feldspar could have become ordered significantly during a major hydrothermal event, and Abdel-Rahman & Martin (1987) have recently documented just such a hydrothermal ordering of the K-feldspar in a Proterozoic intrusive complex in southeastern Ontario. [23]Therefore, we interpret the near-homogeneity of our data on structural state of the K-feldspar as further evidence for the pervasiveness of postcrystallization hydrothermal activity in the St. Francois Mountains complex. [24]Why the ordering did not "proceed to completion" during the proposed event, to produce fully ordered "maximum" microcline ($Z = 1.0$), remains a mystery.

[25]An interesting subsidiary conclusion from our data concerns the "closure temperature" for the K-feldspar ordering process, at least under hydrothermal conditions. [26]Our calculated No values (20.97) indicate quite low values for the temperature of final equilibration of the alkali feldspar in the Butler Hill-Breadtray granite. [27]For the entire range of reasonable pressures, this final equilibration temperature would be well below 300°C (Yund & Tullis 1983). [28]This conclusion is supported by the oxygen isotope data of Wenner (1988), which suggest that the final temperature of re-equilibration of the alkali feldspar throughout much of the St. Francois Mountains complex is > 250 C.

NS-16: Routine trace-element capabilities of electron-microprobe analysis in mineralogical investigations: An empirical evaluation of performance using spectrochemical standard glasses

[1]The importance of careful investigation of the background is illustrated in Figures 1 to 4, where examples are given of the different problems that can be encountered. [2]To some extent, the large number of trace elements present in GSD and GSE poses questions that would be unlikely to arise in natural silicate minerals, for not only must interference from major and minor elements of the matrix be considered, but the possibility of trace-element interference also needs to be avoided.

[3]In favorable circumstances, there are few or no interfering lines, and the continuum will either be horizontal (as for Ag in Fig 1a) or have only a minor positive or negative slope (as for Sn in Fig 1b). [4]In such situations, the background measurements can be located either symmetrically (as is the case for Ag) or asymmetrically (as is the case for Sn) about the analytical line.

[5]In some situations (especially with TAP or PET crystals), an interference will be present. [6]Although pulse-height selection may be used to eliminate interferences due to high-order reflections, it is not a routine procedure, and in most cases the effects can be avoided by judicious selection of the crystal and background offset. [7]If this interference is minor and on only one side of the analytical line, then it can easily be avoided by careful placement of the background offset. [8]If the interference is severe, then selection of a different crystal or analytical line (or both) can usually avoid the problem. [9]This is the case, for example, with Zr and Sb. [10]Using Roman numerals in parentheses to denote the order of the line, the FeK1 (III) interferes on the low side and CaKß1(II) on the high side of the ZrL line if using TAP; however, the background is free of interference if using PET. [11]The KKß1(I) line coincides with SbL1 on PET. [12]No other crystal can be used for this element, therefore, the analysis must be attempted using the SbLß1 line (Fig 1c), with a negative offset of background located to avoid possible interference from trace Te. [13]Despite the reduced intensity of this line, satisfactory determinations of Sb-content were obtained at both 500 ppm (GSE) and 50 ppm (GSD) concentrations (Tables 2, 3).

[14]In a few cases, major interference cannot be avoided. [15]This is the case for In and As in the present study. [16]The InL line is dominated by the KK line (Fig 2a). [17]The AsL line on TAP has major interference from MgK (Fig 2b), but must be used since PbL coincides almost exactly with AsK on LIF, and the element is out of range on PET. [18]These interferences make the determination of In and As very sensitive to differences in the Mg and K contents of the blank and sample matrix. [19]It is only because these differences are small in the present investigation that it has been possible to analyze for both In and As at the 500 ppm level (Table 2). [20]Realistically, it would be necessary to resort to overlap-correction procedures [see, for example, Okumura (1984)] to deal generally with these situations.

[21]The trace analysis of Rh and Ru in GSE illustrates another problem that can arise if there is a significant difference in minor-element content between the unknown and the blank. [22]GSE contains about 800 ppm Cl, whereas GS°C contains only about 50 ppm Cl. [23]Since the ClK peak is located between the analytical peaks for Rh and Ru (Fig 3), it is essential that the Rh and Ru background offsets be located away from the tails of this peak, i.e., on the negative side of the RhL and the positive side of the RuL lines, respectively. [24]If not, and backgrounds are taken symmetrically about these peaks, then incorrect nonlinear background slopes will be determined from the blank owing to the absence of the Cl peak in GS°C (Fig 3a) and its presence in GSE (Fig 3b).

[25]The trace analysis of Au also is difficult in the present study. [26]The FeK(III) line interferes with AuM on PET, hence it is necessary to use the AuL line on LIF. [27]This choice requires that the instrument be operated at an accelerating voltage of 40 kV, with the disadvantage of increasing the volume of X-ray excitation and thus degrading the spatial resolution achievable by microanalysis. [28]Moreover, the continuum dips in the vicinity of the AuL line (Fig 4), making it very difficult to obtain a reliable measurement of background during routine, on-line analysis. [29]The dip is not related to the sample composition, as it has been observed also with other materials (e.g., pyrite and arsenopyrite: Ramsden Creelman 1984) and for other elements (e.g., Sb in sphalerite when using a Ge analyzing crystal: Self et al., 1988). [30]According to Self et al., (1988), such effects are an artefact of the analyzing crystal due to multiple diffraction.

[31]Although beyond the scope of the present study, modeling of the background would probably be the best way of dealing with this problem, since once the sample-independent shape of the continuum has been established for a given spectrometer, the appropriate background-correction could then be calculated for any analytical condition.

[32]Because the results of the present study are being judged against results of "bulk" analyses of homogenized powders, we have chosen to carry out microprobe analyses at 10 widely spaced locations on the glass chips and average these, rather than take 10 replicate analysis at a single (5 to 10m) point. [33]Given that the glasses are homogeneous on the macro scale (Myers et al., 1976), these averages should, therefore, be comparable with the bulk results. [34]This procedure, however, can be expected to reveal inhomogeneity on the micro scale. [35]Barnes et al., (1973) and Heinrich et al., (1977) have clearly demonstrated that such inhomogeneity can exist, even in NBS standard glasses that have been certified as homogeneous on the macro scale.

[36]The present microprobe results also suggest that such micro-inhomogeneity is indeed present in GSE and GSD, as indicated by the relatively large 2 values associated with the element means (Tables 2, 3). [37]The variations that would be expected on the basis of the peak-count statistics if the element distributions were homogeneous are considerably less (Table 4). [38]The basis for this calculation is that for a

homogeneous sample, the measured deviations should fall within 3N/N of the mean concentration, where N stands for the mean peak-counts (Goldstein et al., 1981). [39]It is evident that none of the 30 elements reported in GSD can be considered to be homogeneously distributed on the basis of this criterion, and that of the 39 elements reported in GSE, only Cr, Mn and V are homogeneously distributed.

[40]That micro-inhomogeneity is present also is substantiated by systematic evaluation of results of specific point-analyses. [41]In one case, for example, duplicate analyses on two points less than 10 micrometers apart on GSE showed the Pd-content to be about 56 ppm and 390 ppm, respectively, although the mean of 125 ppm for 10 locations (Table 2) is close to the expected value of 100 ppm found by Myers et al., (1976). [42]In another case, the results of a systematic line-traverse across the GSE chip show quite large variations in W and U at the micrometer scale (Fig 5). [43]Indeed, the overall U-content is lower for this traverse than if averaged over the chip as a whole, suggesting quite marked zonation in the distribution of this element.

[44]A detailed discussion of limits of detection is beyond the scope of the present paper. [45]It should be noted, however, that a variety of procedures have been proposed for the calculation or prediction of detection limits in X-ray emission spectroscopy (Liebhafsky et al., 1960, Ziebold 1967, Pantony & Hurley 1972, Wintsch & Muster 1973, Wittry 1980, Tnian & Claiss 1982, Rdmer 1985, Chappell 1987). [46]As pointed out by Heinrich (1981), "One must conclude that their is no consensus as to what should be a reasonable statistical limit of detection."

[47]The factors that determine the sensitivity of the electron microprobe used for analysis at the trace level are many and complex. [48]They include: 1) the alignment of the electron beam and X-ray spectrometers, 2) the counting time, 3) the accelerating voltage, 4) the beam current, 5) the particular element and the line used to measure it, and 6) the composition of both the sample and the standards. [49]Thus, the distinction between peak and background is limited not only by the statistical uncertainties in the measured X-ray intensities, but also by the systematic errors inherent in the procedure used to determine the background level. [50]As pointed out by Heinrich (1981) ". . . the more carefully the analyst tries to eliminate the counting errors, the more prevalent the systematic errors become in determining the uncertainty of the intensity ratio. [51]Hence it is incorrect in principle and in practice to define a limit of detection solely on the basis of statistical considerations as is so frequently proposed".

[52]Detection limits reported in the present study are empirical and derived on the assumption that the measured concentration (Tables 2, 3) corresponding to the peak height for each element is correct. [53]It is then a simple matter to calculate the concentration corresponding to a specified level of confidence level above the mean background-count (Nb) for a given set of instrumental conditions. [54]The results of this approach can be seen in Table 5, in which detection limits calculated for a 95% confidence level (i.e., 2Nb) are compared for two different analytical conditions. [55]As expected, they show that marked improvements in detection limits are obtained when the beam current is increased from 50 nA to 100 or 150 nA, and the counting times increased from 100 to 300 s. [56]For the majority of elements, the detection limit is well below 50 ppm at the higher beam-current and counting time; apart from Ba, Ru, U and W, the remainder have detection limits close to 50 ppm.

[57]For several elements (As, Cs, Ge, Ir, Pb and U), the measured concentrations in some cases are actually substantially below the detection limits quoted in Table 5. [58]However, the results agree with the "true results" reported by Myers et al., (1976). [59]Thus, although they would not be regarded as significant statistically (at the 95%, confidence level), they are meaningful analytically. [60]Bence et al., (1977) have likewise found that trace-element data obtained with an electron microprobe can be meaningful even where, from the statistical point of view, confidence in the result is low. [61]In their studies, the values obtained from a single initial determination were found to be virtually identical to those obtained after up to 12 replications.

Conclusion

[62]We conclude that the trace-element investigation of silicate minerals by means of electron-microprobe analysis can be readily carried out for a wide range of elements at levels of 50 ppm (and less) using routine procedures. [63]To achieve this, however, it is very important that the background in the vicinity of each analytical line be carefully investigated. [64]Because the procedures are routine, once the background investigations have been completed, it is possible to carry out such analyses in a comparatively short time- frame, typically involving counting times of 100 to 300 s on peaks and backgrounds, with reasonable precision and sensitivity. [65]This practice allows reconnaissance studies on complex, fine-grained mineral assemblages, applicable to programs of mineral exploration and valuation, to be undertaken with confidence.

NS-17: Massive sulfides with fluid-inclusion-bearing quartz from a young seamount on the East Pacific Rise

[1]The hydrothermal material dredged from the summit of the volcano is part of a seafloor hot-spring deposit. [2]It is unlikely that any of the samples are from a sub-seafloor stockwork (Honnorez et al., 1985) because there is no morphological evidence for tectonic exposure such as caldera faulting (Fig 1). [3]The seamount deposits explored with submersibles near 12N and 21N along the East Pacific Rise and described, respectively, by Hekinian & Fouquet (1985) and by Alt et al., (1987) are the closest known analogues to the present dredged deposit. [4]The atacamite crusts are analogous to those observed at the TAG Mid-Atlantic site (Thompson et al., 1988) and East Pacific Rise seamounts (Alt et al., 1987), formed by diagenetic oxidation and remobilisation of copper within sulfide mounds.

[5]Elemental analyses of massive sulfide yield values for Au, Ag, Cu, Zn, Pb, and Fe that are typical for samples from many seafloor sulfide deposits (Rona 1988, Hannington & Scott 1989). [6]The gold and silver values match fairly closely those of the primary Fe and Fe-Zn massive sulfide from TAG (Hannington et al., 1988), as well as massive sulfide from Axial Seamount and the Southern Explorer Ridge (Hannington & Scott 1989). [7]Gold and silver values exceed those in massive sulfides from 21N East Pacific Rise (e.g., Zierenberg et al., 1984). [8]Levels of copper and zinc are lower than in many seafloor samples (Rona 1988). [9]Despite an association with atacamite, there is no dramatic secondary (supergene) Au enrichment in the sulfides, as has been discovered at TAG (Han-nington et al., 1988).

[10]All unusual aspect of the seamount massive sulfide samples is the abundance of quartz and the presence of fluid inclusions within primary quartz. [11]Black smoker fluids are generally supersaturated with respect to quartz as well as amorphous silica at seafloor pressures (e.g., Von Damm et al., 1985, Bowers et al., 1985, Michard et al., 1984), but quartz and, to a lesser extent, amorphous silica are rare within many black smoker chimneys. [12]Black smoker fluids apparently rise nearly adiabatically from a deep reaction-zone where the fluids are in equilibrium with quartz at high temperature and pressure. [13]During rapid upwelling, quartz nucleation is suppressed, and dissolved silica ends up being flushed out into the ocean. [14]The presence of amorphous silica or quartz with sulfides in mounds or chimneys attests to a process that allows nucleation of silica to occur; one possibility is that fluid encounters a regime of slower and more diffuse flow, perhaps combined with substantial conductive heat-loss (Hannington & Scott 1988; their Fig 17). [15]Tivey & Delaney (1986) proposed a similar scenario for portions of massive sulfide mounds that were sealed by late-stage precipitation of amorphous silica.

[16]In contrast to black smoker chimneys that are devoid of silica, the other end of what may be a complete natural spectrum is the silica-rich, sulfide-free chimneys from the Galapagos spreading center (Herzig et al., 1988). [17]These structures, composed of amorphous silica (opal-A), were precipitated at 32 to 42C, based on oxygen isotopic values. [18]Herzig et al., (1988) suggested that fluids responsible for

these inactive chimneys were cooled from high-temperature Si-rich solutions by a combination of conductive cooling and mixing with cold seawater. [19]They hypothesized that associated sulfides may have been deposited in the subsurface. [20]The massive sulfides described in the present paper fall in the middle of the silica spectrum. [21]They are similar to sulfides from other East Pacific Rise seamounts described by Alt et al., (1987) and Hekinian & Fouquet (1985) that contain abundant amorphous silica (opal), as well as quartz that has both replaced opal and has crystallized directly in vugs and fractures. [22]The silica-sulfide-sulfate spires from Axial Seamount (Hannington & Scott 1988) similarly contain abundant amorphous silica. [23]Alt et al., (1987) estimated temperatures of quartz precipitation on the basis of oxygen isotopic values if we assume that the fluid was unshifted from seawater (18O = 0%), the quartz grew between 230 and 250C. [24]If the fluid was shifted to a 18O of +2.0% then the corresponding temperature range was 280 to 320C. [25]These temperature constraints are in excellent agreement with our range of fluid-inclusion-based temperatures, 240 + 35 C. [26]We therefore concur with other workers that moderate-temperature hot springs (in the mid-200°C range) may form substantial silica-sulfide deposits either within seafloor mounds or beneath the seafloor.

NS-18: Thermoluminescence spectra of minerals

[1]TL spectra of minerals exhibit changes as a result of crystal purity (Chee et al., 1988; Down et al., 1985) radiation dose (Rendell et al., 1985) dose rate and thermal history (Strain et al., 1985). [2]In the following section we present results for a number of different rock-forming minerals. [3]These results exemplify the potential value of TL spectra for provenance studies in the case of minerals like Fluorite and zircon and for studies of impurities within minerals.

[4]Calcite is a bright TL phosphor which emits strongly in the orange portion of the visible spectrum (ca. 550-650nm) when doped with manganese. [5]TL spectra of natural Mn-rich calcite (Joplin, USA) and pure synthetic Iceland spar show pronounced differences. [6]After X-ray irradiation the natural calcite sample showed a broad peaks at 150°C and near 400°C (Fig 1a). [7]The spectrum for synthetic Iceland spar under identical experimental conditions exhibited line spectra (Fig 1b). [8]The wavelength region of the emission confirms that light is emitted at Mn sites (Medlin 1968) but to understand why the spectrum has line features or is broad band requires an explanation of the alternative Mn-related recombination sites. [9]These differences are interpreted in the detailed study by Down et al., (1985) in terms of the concentration and solubility of Mn impurity ions. [10]At low concentrations Mn ions exist as isolated defects within the crystal lattice. [11]At higher concentrations of the order of 1000 ppm the solubility limit is exceeded and Mn precipitates in clusters. [12]But solubility is temperature dependent and as the material is heated Mn clusters dissolve and the number of isolated Mn defects increases. [13]Consequently the line features from isolated Mn sites are apparent at all temperatures in the purer Iceland spar crystals whereas in the heavily doped calcite line features only emerge at high temperature and at low temperature the Mn exists as clusters which give broad emission hands. [14]Thermal processing of samples has been used to modify the dynamics of the clustering process (Down et al., 1985). [15]Crushing the calcite also produces changes in intensity of emission which appear to be related to Mn-migration (Khanlary and Townsend 1991).

Fluorite: [16]Studies of thermoluminescence photo-luminescence and optical absorption of natural fluorites from Spain (M1, M2) and USA (M3) (Calderon et al., 1992) have demonstrated that different colour fluorites are characterised by different combinations of rare earth impurities. [17]A key observation is that all three techniques are required as separately they each only detect a selection of the impurities despite the fact that the impurities are all rare earth ions. [18]One obvious reason for this is that naturally acquired radiation doses or laboratory experiments using X-ray irradiation can alter the charge state of the RE ion from RE7+ to RE3+. [19]The sample of green fluorite (MI) exhibited optical absorption characteristic of samarium (Sm2+) and photoluminescence peaks characteristic of samarium and europium (Eu2+). [20]The spectrum of the natural TL showed a mixture of broad peaks and line features from 300-700nm (Fig 2a). [21]When the same sample was cooled, irradiated with X-rays and then reheated, a series of line features, characteristic of Dy3+ transitions was present at 50°C together with a series of broad peaks in the blue region at higher temperatures (Fig 2b). [22]By contrast the sample of yellow fluorite (M2) showed optical absorption characteristic of O3- substitution for two adjacent F-ions and photoluminescence characteristic of cerium (Ce3+) and Eu2+. [23]The spectrum of the natural TL shows a well defined broad peak at 380nm at high temperature but no clearly defined line features (Fig 3a). [24]After X-ray irradiation line features were revealed at low temperatures in the wave-length range 480-680nm (Fig 3b). [25]The majority of these features are at wavelengths characteristic of dysprosium (Dy3+). [26]The dark-blue fluorite (M3) showed optical absorption characteristic of aggregated colloids of atoms of calcium and no photoluminescence. [27]The spectrum of natural TL is dominated by line spectra at high temperature (Fig 4a). [28]After X-ray irradiation the line features reappear at low temperatures and are again characteristic of Dy3+ (Fig 4b). [29]In all three cases the spectra from the natural and the annealed and X-ray irradiated samples allow the samples to be distinguished from each other. [30]In addition the roles played by the rare earth impurities appear complex and they may be varied by thermal and/or radiation treatments. [31]All three techniques give information on the REE impurities but in the case of TL Dy3+ appears to dominate emission of the line spectra.

Zircon: [31]Zircon is a common component of heavy mineral suites and fission track dating of zircons is now a widely-accepted dating technique. [32]TL spectra of natural zircons are dominated by the line spectra characteristic of the rare earth Tb3+ and/or Dy3+ (Chee et al., 1988). [33]The emission spectra of two samples of natural zircon show broad features in the blue region (300-400nm) and a series of line spectra in the region 480-750nm (Fig 5a and b). [34]Both spectra were recorded after 750 Gy X-ray irradiation and at heating rates of 20°C min-l. [35]The Sri Lankan zircon sample shown in Fig 5a shows a strong emission at the red end of the spectrum which is characteristic of Eu3+ whereas the Mexican zircon sample shown in Fig 5b exhibits strong line features characteristic of Dy3 at 100°C and of Tb3+ at higher temperatures. [36]Both spectra contain a broad feature at about 100°C with a peak at 385nm. [37]This broad spectral feature is characteristic of minerals containing SiO4 groups including quartz and feldspars, and may be related to defective Si-O bonds (Chee et al., 1988). [38]As in the case of the fluorite samples discussed above, it is apparent that while several rare earth impurity ions may be present in a zircon crystal, the ions contribute to the TL signal in different ways. [39]The low-temperature signals tend to be dominated by Dy3+, but storage after irradiation and before heating can result in the growth of Tb3+ related emission features at the expense of the Dy3+ ones. [40]Such conversions can take place at unexpectedly low temperatures, and we have monitored the growth of 90°C 630nm Tb3+ line, at the expense of the Dy3+ lines. [41]This work has served to underline the importance of rare earth impurities as radiative recombination centres as well as the complexity of such centres.

The feldspar group: [42]In contrast to the sharp, clearly defined spectral features exhibited by fluorites, TL emissions from the feldspar group are dominated by broad band emissions. [43]All the feldspars show strong emission at the red end of the spectrum (680-730nm), and this emission has generally been attributed to conversion between Fe2+ and Fe3+ impurities that act as recombination sites for either holes or electrons, depending on valency. [44]In contrast to albite, microcline and orthoclase, the samples of plagioclase studied by the Sussex group have shown no strong emissions in the blue spectral region (Dalal et al., 1988; Kirsh and Townsend, 1988) (Fig 6a, b). [45]Broad emissions in the blue spectral region appear characteristic of intrinsic defects modified by association with impurities such as an Al-O-Al group (Kirsh and Townsend, 1988). [46]If the blue emission is caused by electron-hole recombination then defect sites can influence the fraction of the recombinations which are radiative, for example emission intensity may be enhanced where the defects become more complex (e.g., by the presence of Cu2+ impurities near to the hole trap). [47]Data from cathodoluminescence studies of feldspars indicate that emission bands in the blue region may be enhanced by the presence of Cu^{2+} (420nm + 5nm) and Ti4 (460nm + 10nm) (Marshall, 1988). [48]The relative strength of the blue and red emissions varies with the particular feldspar samples measured, but no line spectra, characteristic of rare earth impurity ions, have been detected in any of the spectra that we have examined. [49]There is some evidence from CL studies of natural and synthetic feldspars that RE ions rarely if ever occur in sufficient concentrations in natural feldspars to be effective activators (Marshall, 1988).

Conclusions

[50]The examples given above have served to emphasise the value of TL spectral studies of minerals. [51]TL is a very sensitive tool for probing defects within crystals and the spectra allow both the nature of the electron and hole traps and of the radioactive recombination centres to be explored. [52]The ability to detect low concentrations of impurity ions is of value in its own right, and of potential value for provenance studies.

NS-19: Composition of fluids in quartz: Discrimination of magma pulses in a Caledonian granitoid

[1]The compositions of fluids extracted from the quartz are shown in Table 4. [2]A geochemical study of the Etive granitoid complex recognised that the Starav monzogranite facies was composed of four nested pulses. [3]When data for mole H_2O/CO_2 and atomic ratio Na/K were plotted, it became apparent that the variation in fluid composition mirrored the whole-rock trace-element pattern in discriminating between three out of four pulses.

[4]Moving from pulse 1 to pulse 2 shows a general relative increase in CO_2 with increasing Na/K. [5]Pulse 3 is conspicuous in having the highest relative CO_2, content and shows an overall increase in Na/K with decreasing H_2O/CO_2. [6]Pulse 4 shows a relative increase in CO_2 from the outer margin to its centre, culminating in the CO_2-rich pegmatite. [7]Whereas Na/K values increase with a relative increase in CO_2 in pulses 2 and 3, this ratio falls within pulse 4 towards the centre. [8]The appearance of monazite in this pulse was noted by Barritt. [9]The distribution of U within pulse 4 is bimodal, averaging 3.08ppm in the outer facies and 7.89ppm in the inner facies. [10]The inner facies contains the highest levels of U in the Etive pluton compared with a mean value of 2.7ppm in the rest of the pluton. [11]The inner facies is also host to disseminated molybdenite mineralisation. [12]This mineralised facies is characterized by low Na/K and low H_2O/CO_2.

[13]The two phase aqueous inclusions from all four magma pulses have low salinites and temperatures of homogenisation with means ranging from 152°C to 233C, suggesting that a moderate temperature, low salinity aqueous fluid was present in all magma pulses. [14]The fact that most inclusions are equant or ellipsoidal in shape strongly suggests they are of primary origin and therefore that their composition is unique to each pulse. [15]Since the variation in fluid composition discriminates between pulses this suggests that any late-stage fluid overprint was insufficient to mask the primary fluid signature. [16]It should also be noted that in pulse 3 the order of samples which define the fluid compositional trend is mirrored exactly in the bulk rock K/Rb and Nb/Y values. [17]The presence of abundant CO_2-water immiscible liquid inclusions in material from magma pulse 3 suggests that a different source was involved. [18]In agreement with the bulk analytical work the presence of CO_2 and high temperatures of homogenisation from these inclusions supports the interpretation that pulse 3 represents an influx of CO_2-rich magma.

[19]The range of Na/K atomic ratio values for the Etive samples, excluding the pegmatite fall within the span of values quoted for magmatic fluids by Wilkinson and Hansteen and Lustenhouwer. [20]In contrast, Wilkinson notes that low-temperature retrogressive metamorphic fluids in Cornubian granites show Na/K values ranging from 9.7 to 18.3 atomic ratio. [21]These data strengthen the evidence that the Etive fluids trapped in quartz are primarily magmatic. [22]The quartz-microcline pegmatite sample which occurs within pulse 4 contains higher H_2O and CO_2 than its host and has a Na/K value of 7.25 atomic ratio. [23]Thermometric data yields Thtot 166 200°C and a low salinity of 3% which are similar to the host granite. [24]However, the higher concentration of volatiles and relatively higher Na are consistent with the formation of the pegmatite by slow cooling of residual melt.

[25]These results show that a combination of H_2O, CO_2, Na and K data from fluids extracted from fluid inclusions in quartz from a granitoid, supported by thermometric data, can highlight the existence of separate magma pulses and complement whole-rock geochemical data in fingerprinting granitoid facies. [26]They also point to the combination of low H_2O/CO_2 and low Na/K values as indicative of U and Mo mineralisation.

NS-20: Deformation textures in pyrite from the Vangorda Pb-Zn-Ag deposit, Yukon, Canada

[1]The Vangorda orebody has undergone polyphase deformation and metamorphism under greenschist facies conditions. [2]Five distinct sulphide lithofacies have been recognised and their textures reflect the response of the sulphides to various degrees of brittle and ductile deformation.

[3]Primary depositional pyrite textures such as colloform and growth banded grains together with relict spheroidal and framboidal aggregates are only rarely preserved in the Vangorda sulphides. [4]Deformation, recrystallisation and grain growth textures predominate. [5]Pyrite deformation textures identified in this study include brecciation in cataclastic shear zones, grain fracturing. grain boundary sliding, preferred pyrite grain shape orientations, pressure solution, dislocation structures (slip lines and dislocation walls), subgrain formation and dynamic recrystallisation. [6]These textures indicate that the pyrite in the Vangorda deposit deformed by both brittle and ductile mechanisms. [7]The deformation processes, in general, have led to an overall reduction in grain-size. [8]Post-deformation annealing has resulted in an increase in relative grain-size, formation of equant grains and development of pyrite porphyroblasts.

[9]Grain fragmentation and axial cracking indicate that brittle deformation of pyrite grains and of the massive pyrite has occurred throughout the deposit. [10]Breccia textures and pyrrhotite-magnetite-sphalerite shear zones are localised in high-strain zones that appear to be anastomosing D2 fault zones on the limbs of the D2 fold. [11]Similarly, textures indicating strong plastic deformation of pyrite (bands of dynamically recrystallised grains and preferred grain-shape textures) are also restricted to localised areas. [12]The partitioning of deformation textures, both brittle and ductile, within the Vangorda orebody may be interpreted to indicate local strain or strain-rate partitioning during deformation. [13]As the orebody and host rocks appear to be uniformly metamorphosed at mid-greenschist facies conditions, the brittle and ductile strain partitioning indicates local variations in sulphide/matrix rheologies. [14]High strain zones may be localised in the limbs of D2 folds or along D2 fault zones. [15]Reaction enhanced ductility may have been produced by the formation of pyrrhotite-sphalerite-magnetite assemblages in shear zones. [16]D2 fault zones may also have been the locus of transient high pore-fluid pressures that permitted the deformation to occur well into the cataclastic deformation regime thus producing the breccia textured pyrite.

[17]The plastic deformation textures in pyrite found in this study (slip line, kink hand subgrains, dynamically recrystallised grain and preferred grain shape orientations) also indicate that, at geological strain rates, plastic deformation of

pyrite occurs well below the threshold of $450^{\circ}C$ at 300 MPa confining pressure determined experimentally in the laboratory. [18]In addition relict deformed spheroidal a framboidal textures together with overgrowth features indicate that pressure solution played an important role in the deformation of pyrite in the Vangorda deposit.

[19]Post-deformational thermal annealing in the Vangorda deposit, as in the other Anvil District deposits, resulted in the formation of foam textures with 120 triple junctions together with grain boundary migration grain growth and porphyroblast formation. [20]The annealing event has largely obscured and destroyed the earlier depositional, diagenetic, overgrowth and deformation textures tending to increase the grain size and produce homogeneous granoblastic pyrite ores.

[21]The tight to isoclinal, similar, fold style and complex internal deformation indicates that the Vangorda deposit has undergone significantly high strains. [22]Strain partitioning has produced breccia zones and shear zones in part controlled by the sulphide and matrix rheologies. [23]Shear zones in particular are localised in the baritic massive sulphide facies. [24]Shear zones have long been known to act as conduits for fluids during deformation, and fluids are well known to affect the mechanical response of rocks during deformation. [25]To date, a full appreciation of the role of a fluid in the deforming Vangorda deposit has not been assessed. [26]However, scaling of cataclastic zones and fractures by quartz, carbonate, and often pyrite, together with the occurrence of overgrowths on grains indicates that fluid infiltration and mobilisation did occur, and likely played an important role in the mechanical response of the sulphide rocks.

[27]The precise effects of pore fluids on the ductile deformation of pyrite is largely unknown, and is beyond the scope of this paper. [28]Textural evidence, however, indicates that pressure solution is an important deformation mechanism in naturally deformed pyrite. [29]It may be expected that the focusing of a fluid phase along zones of increased strain (i.e., shear zones) may significantly reduce the flow stress required to induce crystal plastic deformation1 in pyrite, in much the same way it affects the mechanical response of quartz and olivine. [30]The effects of fluid chemistry on rock and mineral deformation are not well understood, although Hobbs suggests that deformation and metamorphic reaction are closely tied. [31]The deformation of pyrite in deposits such as Vangorda may be expected to have not only dramatically changed the textural characteristics of the ore but may also be expected to have affected the chemical and isotopic signatures.

NS-21: A supposed sovite from Oldoinyo Lengai, Tanzania: result of extreme alteration of alkali carbonatite lava

[1]Chemically, BD83 is a calciocarbonatite. [2]However, the textures which range from the fine grain size and lath-shaped morphology of the calcite, to the inter-grain porosity and lattice-like apatite, are unlike those found in plutonic or hypabyssal sovites. [3]Moreover, minerals of the hollandite-cryptomelane-romanèchite group are typically found in near-surface environments, and the only previously-reported example of the group from carbonatite is hollandite from a weathered carbonatite at Sallanlatva, USSR, where it occurs as a secondary mineral in cavities with limonite, baryte and pyrolusite (Kapustin 1973).

[4]It is noted above that, in containing lath-shaped carbonate crystals, BD83 is texturally similar to the modern carbonatite lavas from the volcano. [5]To suggest that BD83 derives from a natrocarbonatite bonatite precursor, is to enter a debate that has arisen as to the origin of calcium carbonatite extrusives. [6]Some, such as those at Kerimasi, Tanzania (Manano and Roeder 1983, Kaiserstuhl, Grmany (Keller; 1981, 1989) and Fort Portal, Uganda (Barker and Nixon, 1989), contain platy crystals of unrecrystallised, zoned calcite, and undoubtedly represent extrusion and consolidation of primary calcium carbonate liquid. [7]However, there are others at Kerimasi (Hay, 1983), and also at Tinderet, Kenya (Deans and Roberts, 1984), Homa, Kenya (Clarke and Roherts, 1986) and Kaluwe Zambia (Turner 1988), in which the lath-shaped phenocrysts of calcite are polycrystalline aggregates and have been interpreted as pseudomorphs after original crystals of the alkali carbonates nyerereite and gregoryite; on these textural grounds, the rocks are suggested as being altered alkali carbonatite lavas, originally similar to the Oldoinyo Lengai natrocarbonatite lavas. [8]However, in the case of the Kaluwe carbonatites, some of the laths are dolomitic and could not derive from natrocarbonatite (Ngwenya and Bailey, 1990).

[9]In a contribution to this debate, Dawson et al., (1987) describe the altered alkali carbonatite lava GA47 and show that it is compositionally intermediate between pristine alkali carbonatite and calcite carbonatite: they also speculate the more extensive alteration with further leaching out of the remaining alkalis, might give rise to a calcite rock.

[10]If a convincing case is to be made for a natrocarbonatite protolith for BD83, it is important to be able to recognise two sets of features in BD83, i.e., those that might be inherited from a natrocarbonatite parent and those associated with extensive alteration. [11]Features possibly inherited from a natrocarbonatite precursor are:

[11a]1. The texture is similar to that in the natrocarbonatites.

[11b]2. The REE concentrations (Table 1) and chondrite- normalised distribution pattern of BD83 (Fig 5) are very similar to those in the natrocarbonatite lavas.

[11c]3. BD83 contains a very distinctive 'tracer' spinel, high in Mn, Mg, and Fe3 + (Table 3) that also occurs in both pristine and partly-altered natrocarbonatite lavas at Oldoinyo Lengai.

[12]New features compatible with alteration of the protolith are:

[12a]4. The bulk chemistry of BD83 represents the culmination in a 'trend' towards Ca enhancement, and Na, K, Cl and S depletion, already noted in partly altered natrocarbonatite (Table 1).

[12b]5. BD83 consists mainly of Sr-bearing calcite, that also makes its appearance in the groundmass of the partly-altered natrocarbonatite (Table 2).

[12c]6. The high 18O content of the specimen Is indicative of equilibration with meteoric water. [13]This accords with the porous texture of the rock, which itself strongly suggests some leaching process.

[14]It is suggested that these features collectively, if not individually, and the progression of some features from those already documented from partly altered natrocarbonatite (Dawson et al., 1987), provide strong circumstantial evidence for the formation for BD83 by the alteration of a natrocarbonatite precursor. [15]There is, of course, incontrovertible evidence, in the form of relict nyerereite, for a parent natrocarbonatite for the partly altered natrocarbonatites GA47 and BD4162, which are suggested as representing an intermediate stage in the alteration process.

[16]The minerals in the natrocarbonatites (including complex carbonates, FeS-MnS", MnFe spinel, sodic sylvite and Na-Si apatite) are highly unusual and metastable solid solutions that result from crystallisation of a dominantly-carbonate high-temperature liquid (Dawson et al., in press). [17]Low-temperature alteration has lead to breakdown of the solid solutions to give the relatively simple mineralogy of BD83, with redistribution of some elements and major loss of others.

NS-22: The stabilities of secondary tin minerals: abhurite and its relationships to Sn(II) and Sn(IV) oxides and oxyhydroxides

[1]In contrast to the case of Pb(II), titration of an oxygen-free aqueous solution of tin(II) chloride with oxygen- free aqueous sodium hydroxide shows no distinct end-points. [2]Neutralisation of an acidic solution of tin(II) chloride (for example 0.02 M) with NaOH-(aq) (for example 0.11 M) results in the precipitation of abhurite between pH 2.40 and 3.20. [3]At all temperatures and chloride concentrations studied, abhurite is the first phase to crystallise from solution. [4]As the chloride ion concentration increases, the pH at which abhurite will form falls, as expected; it crystallises at about pH 1.3 in solutions containing about 0.8 M chloride. [5]As the concentration of OH- increases the chloride ions of the complex species in solution are gradually replaced, and Sn604(OH)4 precipitates above a pH of about 3.20. [6]This phase dominates about pH 5.58.

[7]The extent of this and related phases is uncertain, a fact reflected in the formulation of a number of compounds precipitated from tin(ii) solutions, including those containing chloride. [8]Proposed compositions for hydrous tin oxides range from Sn(OH)2, synthesised by an anhydrous organometallic method (Honnick and Zuckerman, 1976), to 5SnO2H2O (Donaldson and Moser, 1961). [9]Donaldson (1961) has prepared crystalline hydrous tin oxides, which have had the formulae 5SnO.2H2O and, latterly, 3SnO.H2O ascribed to them (Howie and Moser, 1973). [10]The discrepancy in composition (one mol H2O per fifteen mol SnO) is attributable to the presence of chemisorbed water on the surface of the microcrystalline solid (as verified by IR measurements). [11]The true formula of the oxide, which corresponds to the mineral hydroromarchite, is by comparison of powder X-ray data, Sn604(OH)4 (Howie and Moser, 1973).

[12]Solid phases produced in the intermediate pH range are mixtures of the tin oxyhydroxide and tin hydroxychloride, with the ratio of basic tin(ii) chloride to tin(ii) oxyhydroxide decreasing as the pH of the solution increases. [13]As indicated previously, an increase in chloride concentration extends the range of stability of abhurite and in certain solutions it persists to pH6 (Donaldson et al., 1963). [14]This may have great significance with respect to the natural occurrence of abhurite.

[15]A stability constant for abhurite (KH+) has been derived in terms of equation (1), using the data of Table 2. [16]Log KH+(298.2 K) Sn2Cl6(OH)1406(s) +26H+ (aq) = 21Sn2+ (aq) + 16Cl (aq) + 2OH2O(l) (l) is equal to-31.9(7) and this value in turn leads to one for fG (abhurite, s, 298.2 K), of-7602.2(7.4) kJ mol-l, using corresponding values for component ions and water taken from the compilations of Robie et al., (1978) and Krauskopf (1982). [17]Errors associated with value of the free energy of formation of the aqueous Sn(II) ion have not been included in the above calculation. [18]The result is clearly more accurate than the former value reported (Randell and Murakami 1930) for the basic tin(ii) chloride, 'Sn(OH)CL', a formula which is incorrect (vide supra). [19]These new quantities have been used to construct an equilibrium model for the formation of the basic tin(II) chloride with respect to tin oxides and oxyhydroxides in order to elucidate the mineralogical relationships of tin corrosion.

[20]Free energies of formation at 298K of Sn(ii) and Sn(IV) salts romarchite, cassiterite and SnCl2 are 259.94, -519.90 and -282.00k mol, respectively (Robie et al., 1978; Krauskopf, 1982; Barner and Scheuerman, 1978, respectively). [21]All other thermodynamic data necessary for the calculations were taken from the usual source (Robie et al., 1978). [22]Stability field diagrams for the SnO-HCl-H2O system at 298.2 K are shown in Fig 1. [23]These illustrate the relationship between abhurite and romarchite. [24]Under natural saline conditions, for example in seawater with chloride concentrations about 0.5M and pH about 8, romarchite (or its hydrated analogue hydroromarchite) is the stable phase. [25]Romarchite is probably the thermodynamically stable phase with respect to hydroromarchite, but this is not completely certain. [26]In nature, and at neutral pH, both phases are found together (Organ and Mandarino, 1971), in particular on corroding tin objects recovered from saline and similar conditions.

[27]Increasing salinity and reduction in pH gives rise to conditions which favour the formation of abhurite. [28]Abhurite was first observed on the surface of corroding tin ingots in surface blisters where the pH of the encapsulated solution was approximately 1. [29]Such high acidity would not be unexpected in an undisturbed micro-environment, and results from the hydrolysis of tin ions. [30]Basic tin(ii) salts on the surface of corroding tin objects have been reported on a number of occasions. [31]Some of these are undoubtedly abhurite and its occurrence may be more frequent than might at first be thought. [32]It can persist, together with hydroromarchite, up to pH6 under highly saline conditions.

[33]The compound SnCl2 does not appear on the stability field diagram; very high chloride concentrations and extremely acidic conditions are required for its stabilisation. [34]Thus reports of SnCl2 on corroded tin objects recovered from sea water are probably spurious, with the 'chloride containing' salt described more likely being abhurite.

NS-23: Sulphide mylonites from the Renstrom VMS deposit, Northern Sweden

[1]From the microtextures observed in the Renstrom sulphides it can be seen that pressure solution and grain boundary sliding have occurred during the shear zone metamorphic event.

[2]With reference to the P-T diagram of Marshall and Gilligan (1987) (Fig 14), pyrite in the Renstrom sulphides would have behaved in a plastic fashion under the conditions of both the regional and shear-zone metamorphism. [3]Therefore, pressure solution and associated grain boundary sliding are theoretically possible within the sulphide ores of Renstrom. [4]The microtextures of the host rocks suggest deformation in the temperature range 300-400C. [5]For instance, quartz shows extensive dynamic recrystallisation (Fig 15), which indicates temperatures over 300°C (Nicolas and Poirier, 1976). [6]Also, bent twin planes and deformation twinning in dolomite suggests temperatures of greater than 410 °C (Higgs and Handin, 1959). [7]The temperature of deformation indicated from microtextural features is in agreement with that indicated by the sulphide isotopic thermometry, i.e., 320-450C.

[8]Deformational textures are more commonly observed in pyrite rather than in the other sulphide minerals in the Renstrom ores, probably due to the higher relative strength of pyrite compared with the other sulphide minerals. [9]Pyrrhotite does show pressure lamellae in most sections studied optically, but as pyrrhotite is weak at low temperatures and pressures, it could be argued that these were produced after the main shearing episode, possibly on uplift to shallower crustal levels. [10]Pyrite that has been sheared shows later cataclastic textures and arsenopyrite than shows cataclastic textures, with fine-grained fractured arsenopyrite associated with euhedral pyrite grains. [11]This suggests that arsenopyrite failed in a brittle manner in areas where pyrite recrystallised, indicating that arsenopyrite may have been stronger than the pyrite. [12]Many authors (e.g Stanton 1972, Clark and Kelly, 1976; Marshall and Gilligan, 1987) have suggested that galena is the weakest sulphide, followed in increasing strength order by pyrrhotite, chalcopyrite, sphalerite and pyrite. [13]These authors also suggested that these middle three sulphides are probably of similar strength to most carbonate rocks and that some silicates may be weaker than pyrite. [14]These ideas are in agreement with what is observed in the Renstrom deposit. [15]However, the meta-dolomite at Renstrom appears to have been stronger than the pyrite as it forms resistant porphyroclasts and boudin structures within the pyrite ores. [16]This indicates that dolomitic carbonates are stronger than calcite limestones and sulphides.

Conclusion

[17]Sulphide mylonites in the Renstrom VMS deposit have formed by pressure solution processes that have been initiated as a response to high strains and water:rock ratios experienced in discrete shear zones that crosscut the area. [18]Similarly deformed sulphides are probably common in other ancient VMS deposits, but have not been widely reported. [19]The microtextures of the Renstrom sulphides, especially the pyrite, indicate that extensive plastic deformation has occurred. [20]The dolomite that hosts the sulphides appears to be the strongest mineral in the ore zones, followed in order of decreasing strength by arsenopyrite, pyrite, sphalerite, pyrrhotite, chalcopyrite and galena. [21]This agrees with that proposed from experimental work on the deformation of the common sulphides by authors such as Stanton (1972 and references therein), Clark and Kelly (1976), and Marshall and Gilligan (1987). [22]The temperature of the retrogressive shearing event at Renstrom was around 400C; this is shown by sulphide isotopic thermometry and from interpretation of deformation textures within the sulphides and the host rock carbonates and silicates. [23]Pressure solution appears to have been the most common deformation mechanism, producing banded pyrite mylonites and indicating a fluid-assisted deformation episode.

NS-24: Low-pressure corona textures between olivine and plagioclase in unmetamorphosed gabbros from Black Hill South Australia

[1]The multiple corona textures described above formed in an at least 7-component system involving the components SiO2, Al2O3, FeO, MgO, CaO, NaO and H2O. [2]The number of phases involved in the texture, on the other hand, appears to be no larger than 4 (olivine, orthopyroxene, amphibole, plagioclase) and the corona-forming reaction is of a high thermodynamic variance. [3]It is therefore extremely difficult to interpret the reaction-forming processes on the basis of phase diagrams. [4]Here, we rely on detailed textural observations and the descriptions above to constrain some of the corona-forming conditions and processes.

[5]Clearly, the coronas reflect the growing instability of the olivine-plagioclase equilibrium also reflected by the complete absence of olivine in the more evolved gabbronorites. [6]In some olivine gabbros the original presence of olivine can only be inferred from the occurrence of coronas which no longer contain any olivine core. [7]It is an important point that the full coronas are not developed in the troctolites which in terms of their bulk chemistry are not greatly different to the olivine gabbers. [8]In the troctolites only the orthopyroxene shell is formed and there is textural evidence suggesting that the orthopyroxene shell formed above the solidus by reaction with melt (see above). [9]Subsequently increasing aH2O, thought to be important in symplectite growth, would enlarge the stability field of olivine with respect to orthopyroxene (e.g., Kushiro, 1969) and therefore not favour the formation of orthopyroxene rims.

[10]In the olivine gabbros, amphibole and symplectite shells are formed in addition to the orthopyroxene shell. [11]This change from coronitic to vermicular textures might be interpreted as an indicator for a distance beyond which diffusion became too restricted for broad reaction front migration. [12]However, the plagioclase in the symplectite is near pure anorthite and is a second, new reaction product now being produced together with opx. [13]Textural evidence, in which the symplectites impinge on, or grow into plagioclase grains (Fig 1d), or along plagioclase-plagioclase grain boundaries, argues strongly for a sub-solidus origin of the symplectitic part of the texture. [14]Additionally, corona textures are formed around plagioclase inclusions within olivine but they are not developed at the olivine-pyroxene contacts. [15]Fig 1a shows cumulus grains of olivine and plagioclase that must have crystallized prior to the intercumulus augite they are both included within. [16]A multiple corona is developed at boundaries between the olivine and plagioclase but not at olivine-augite boundaries (though note in Fig 1 that a thin orthopyroxene rim exists between the olivine and the augite consistent with an above-solidus formation for orthopyroxene). [17]This also suggests a sub-solidus origin as the grain boundaries must have been fixed prior to corona growth. [18]We therefore suggest that the addition of a second product phase in the outer, vermicular corona balances the vanishing of melt as part of the reactant assemblage in order to maintain the variance of the reaction. [19]The absence of symplectite coronas at olivine-augite boundaries reflects a greater chemical stability between olivine and augite than between olivine and plagioclase (augite is, at most, rimmed by amphibole).

[20]The observation that some coronas consist of just the orthopyroxene rim followed by a symplectite of anorthite containing orthopyroxene vermicule requires equation 2 to be written without amphibole. [21]Increasing the anorthite component of the plagioclase frees SiO2 for reaction with olivine to produce orthopyroxene, however, this can be balanced only by loss of Na: [...] where x is the mole fraction of albite in plagioclase which is about 0.35 in the case considered here. [22]If this is correct then the driving mechanism for symplectite formation may have been a potential gradient in Na during subsolidus cooling.

[23]The reason for the sub-solidus anorthite-orthopyroxene symplectite formation in the olivine gabbros but not in the troctolites remains somewhat obscure, though the troctolites have a more cumulate texture and the removal of intercumulus liquid may have resulted in an absence of components, including volatiles, necessary for symplectite growth. [24]In particular, a certain critical H2O component may be required for the full corona formation as, at magmatic temperatures, plagioclase stability is decreased by increasing PH2O. [25]Inward collapse of a hydrothermal system, set up in the country rocks, shortly after solidification of the plutons is thought to have produced localized 'coarse zones' where the gabbros become completely uralitized (Turner, 1992). [26]We suggest that this may also have promoted diffusion and growth of the complete multiple textures. [27]This is supported by detailed compositional mass balance analysis of anorthite-orthopyroxene symplectite growth (van Lamoen, 1979; Nishiyama, 1983; and Mongkoltip and Ashworth, 1983) indicating diffusive growth under conditions where several components have restricted diffusion ranges.

[28]The development of the amphibole shell is interpreted to post-date the main symplectite formation, following the reaction: [...] and may be related to a general hydration of the pyroxene margins seen in the gabbros at Black Hill (note from Table 1, the anorthite contains sufficient Na to balance the amphibole). [29]This is indicated by the occurrence of coronas that lack amphibole rims (e.g., Fig 1f) and the textural evidence that, where it does occur, amphibole is replacing orthopyroxene and the outer symplectite. [30]In Fig 1c amphibole appears to be migrating into the orthopyroxene shell, in places reaching right to the olivine core, whilst on the other side it is seen migrating up orthopyroxene vermicules in the symplectite and elsewhere replacing them. [31]The conspicuous compositional zoning in the amphibole (Fig 1c, Table 1) supports this notion with half of the shell on the orthopyroxene side being Al2O3-poor and Mg-rich whilst the other half is Al2O3-rich and Mg-poor. [32]The mid-point between these two halves is taken to be the original orthopyroxene-symplectite boundary.

[33]Mass balance calculations can be used to see if the bulk composition of the three shell corona can be expressed in terms of the two reacting components. [34]The relative volumes of each reaction product component (estimated above for the corona in Fig 1b) were calculated by integrating the area of each phase on probe photographs. [35]The bulk corona composition can then be estimated by multiplying the abundance of each component in each product phase by the relative volume for that phase and its density. [36]Table 2 shows the results of least squares mixing of the host olivine and plagioclase to approximate the estimated bulk composition of the corona. [37]The sum of residuals squared is moderately high (9) which may partially reflect the errors in calculating the volumes of components and the likelihood that the orthopyroxene rim partially formed above the solidus in open system reaction (e.g., Johnson and Carlson, 1990) with a liquid phase. [38]However, it is important to note that the worst match is that for Na2O which is significantly lower in the bulk symplectite relative to the estimated symplectite. [39]This provides support for equation 3 and the

notion that a potential gradient in Na may have driven symplectite formation. [40]The system must also have been open with respect to H2O and TiO2 which do not occur in either reactants. [41]Nevertheless, the calculations show that the products can be broadly accounted for by reacting olivine and plagioclase in the proportions 1:3. [42]This correlates with the symplectite comprising 71% of the total corona and suggests that the original plagioclase-olivine boundary is represented by the orthopyroxene- or amphibole-symplectite boundary, consistent with the findings of Mongkoltip and Ashworth (1983) that Si and Al are relatively immobile.

[43]In conclusion, it can be said that due to the high thermodynamic variance of the corona textures described, phase diagram considerations are difficult to apply. [44]However, from textural evidence we interpret (1) formation of the inner, orthopyroxene corona mantling the olivines close to the solidus and possibly in the presence of magma; (2) formation of the outer, vermicular corona during sub-solidus conditions; (3) formation of the central incomplete hydrous amphibole/biotite corona during subsequent hydration of the system. [45]The coronas formed in response to compositional gradients (Na and H2O) during igneous cooling rather than during a subsequent (metamorphic) event.

NS-25: Petrogenetic implications of garnets associated with lithium pegmatites from SE Ireland

[1]The origin of garnets in granitic rock and lithium pegmatites has long been problematical since many of these rock were not intruded at the great depths commonly believed to have been responsible for garnet nucleation. [2]Their presence in granitic rocks has allowed some authors to constrain the petrogenesis of the host rocks by relating host rock geochemistry, field and textural relationships to garnet chemistry e.g., Green and Ringwood (1968), Fitton (1972), du Bray (1988) and Stone (1988). [3]Until recently, this has not been the case for Li-rich pegmatites (cf Baldwin and von Knorring 1983). [4]The Leinster garnet data are assessed firstly in terms of the partial melting of a Li-rich protolith model favoured by McArdle and Kennan (1987 and 1988) and then in the light of the 'magmatic' model of Whitworth and Rankin (1989) and Whitworth et al., (1989).

[5]Pichavant et al., (1988) showed that Peruvian macusanite, a natural analogue of Li pegmatite magmas (London et al., 1988), was formed by partial melting of crystal material such as altered rhyolitic lavas or argillaceous material. [6]High Li, B and H2O in this magma imparted great mobility despite its high SiO2 content. [7]This, together with little evidence for assimilation of other material during ascent, led Pichavant et al., (1988) to postulate a rapid rise through the crust. [8]Kennan et al., (198h) and McArdle and Kennan (1987, 1988) have proposed a similar model for the generation of the Aclare pegmatite magma. [9]Their model involved an exhalative origin for the Li which was then concentrated by a volcanic-related hydrothermal system. [10]Melting of this coticule/tourmalinite-bearing Lower Palaeozoic lithium-enriched metasediment (McArdle and Kennan, 1988) then gave rise to a H20 and Li-rich magma which formed the Aclare pegmatite.

[11]Green and Ringwood (1968) showed that almandine is present at liquids temperatures in rocks of andesitic or dacitic composition derived by partial melting of pelitic sediments at pressures 9 kbar or depths in excess of 25 km. [12]A mol.% of spessartine 10% indicated that garnet formed at a depth 18 km but with an increased spessartine component of 20 to 25 mol.%, almandine becomes stable at 12 km depth (Green and Ringwood, 1968 Green, 1977). [13]However, Fitton (1972) pointed out that liquids garnets formed by partial melting of pelitic sediments are euhedral, contain few inclusions and have less than 10 mol.% spessartine (see also Green and Ringwood, 1968). [14]These characteristics are dissimilar to those of the Aclare garnets which are euhedral, contain abundant inclusions and are very rich in spessartine, implying that they have not been the products of partial melting. [15]Furthermore, Harrison (1988) postulated that an increased water content in the Cairngorm Granite, Scotland, may have increased garnet stability within the marginal parts of the intrusion. [16]An aqueous phase was certainly present for much of the crystallisation of the Aclare pegmatite (Whitworth, 1989; Whitworth and Rankin, 1989) and played an important role in its development. [17]One such role may have been the assistance of garnet growth through the transfer of material to the nucleation site (cf Burnham and Nekvasil, 1980). [18]Thus, it is not inconceivable that the Li pegmatites and their garnets may have been the products of crystallisation from a Li-and H2O-rich magma derived by partial melting of the crust at a depth of around 15 to 18 km.

[19]Garnets may also form by assimilation of material into the magma (e.g., Green and Ringwood, 1968; Allan and Clarke, 1981) but this is an unlikely origin for the Aclare garnets since there is no evidence of assimilation of schistose material in the form of xenoliths, or of disturbances in the isotopic composition of the fluids (Whitworth et al., 1989).

Magmatic model: [20]Fluid inclusion isochore modelling and stable isotope studies have shown that the Leinster Li pegmatite bodies could have been formed by isobaric cooling of a pegmatitic fluid derived from the nearby Leinster Granite at 675°C and 2.7 kbar (Whitworth and Rankin, 1989, Whitworth et al., 1989), i.e., magmatic in origin, in contrast to the model discussed above. [21]Petrological and isotopic data indicate that the spodumene pegmatites were formed at temperatures <460°C and at depths <8 km. [22]Fluid-inclusion data combined with studies of the local metamorphic conditions (McArdle, 1981; McArdle and Kennan, 1987) also suggest that the pegmatitic magma could not have formed at depths 15 km (Whitworth and Rankin, 1989). [23]These studies also agree with a previous study of the Leinster pegmatites by Scoon (1978) and with the general pressure constraints for Li pegmatites presented by Cerny (1982).

[24]Garnets formed as low-pressure precipitates from peraluminous granitic magmas have fractures which are very similar to those of the Leinster spodumene pegmatite and alpite-hosted garnets, i.e., euhedral shape, lack of reaction rims, mol.% spessartine 10% and hosted by chemically evolved rocks (cf Leake, 1967; Manning, 1983; Baldwin and von Knorring, 1983; du Bray, 1988; Harrison, 1988; Stone, 1988; Whitworth and Feely, 1989). [25]Many spodumene-pegmatite-hosted garnets have very high spessartine (Table 1 and Fig 2), a feature that Baldwin and von Knorring, 1983) consider is only achieved in Li-rich pegmatites. [26]However, a few garnets from the Li-poor Galway Granite and Thailand also have high spessartine contents (Leake, 1987; Manning, 1983; Fig 2), although these garnets do not appear to be typical of the garnet populations from these intrusions as a whole. [27]Baldwin and von Knorring (1983) also noted crystallisation temperatures as low as 550°C for garnets in the Rosendall pegmatite, Finland. [28]Crystallisation temperatures for pegmatite-alpite-hosted garnets have not been determined for the Leinster samples but oxygen isotope crystallisation temperatures of 392 to 642°C were obtained for barren pegmatites in the Leinster pegmatite belt (Whitworth et al., 1989). [29]Slightly lower temperatures are envisaged for the spodumene pegmatites (Whitworth, 1989; Whitworth et al., 1989). [30]Aplite at the contact of the Aclare pegmatite is believed to have formed at around 675°C (Whitworth, 1989). [31]Thus, those chemical and textural features described above, in combination with P-T studies, indicate that the Aclare garnets formed as a result of low-pressure crystallisation from the Li-rich pegmatitic belt.

[32]In addition to increased garnet stability at lower pressures (Green, 1977), increased Mn concentrations in the garnet suggest a Mn-rich medium in which crystallisation occurred. [33]The sparse development of garnet in both pegmatite and aplite indicate that the areas of Mn enrichment were relatively uncommon, a conclusion backed up by the low overall MnO contents of the Aclare pegmatites (Luecke, 1981; Whitworth, 1989). [34]A mechanism to explain the localised presence of garnets in silica-rich magma chambers was proposed by Hildreth (1981). [35]This model involves hydroxyl complexing of Mn in an ascending fluid phase to produce discrete areas of Mn enrichment in the roof zone of the magma chamber. [36]This mechanism may also explain the local concentrations of spessartine since the evolution of this pegmatite body was characterised by the generation of an

aqueous phase (Whitworth, 19X9). [37]This fluid promoted the coarse grain size (cf Fenn, 1986) and allowed transport of material to the crystallisation fronts (cf Burnham and Nekvasil 1986). [38]Aqueous fluid released during the evolution the pegmatitic belt is believed to have complexed available Mn and transported it to the nucleation site, possibly chloride- or silica-rich complexes discussed by Burnham and Nekvasil (1986). [39]This process locally increased the Mn content of the fluid allowing garnets to crystallise while the chemistry of the belt as a whole evolved (Whitworth, 1989). [40]A similar model for the occurrence of garnet in the marginal portions of the Cairngorm Granite, Scotland, was proposed by Harrison (1988) who also noted that biotites coexisting with spessartine-rich almandines were Mn-rich.

[41]According to Cerny and Hawthorn (1992) and Baldwin and von Knorring (1983), increasing chemical evolution of a pegmatite fluid produced increasingly Mn enriched and Fe depleted garnets within the pegmatite. [42]Whitworth (1989) considered that aplite at the margin of the Aclare pegmatite was the first rock to crystallise in the body. [43]Garnets within this zone have much lower Mn than those formed during the later stages of spodumene pegmatite crystallisation (Table 1), suggesting that the aplite was not as chemically fractionated as the Li pegmatite. [44]A similar trend was observed by Baldwin and von Knorring (1983) for African granite pegmatites where garnets in the marginal zones were Mn-poor, whereas those in the core were Mn-rich, having spessartine 90 mol.%.

Conclusion

[45]Within the internally zoned Aclare pegmatite body, garnets are confined to garnetiferous spodumene pegmatites, garnetiferous aplite and the surrounding schists. [46]In general, the garnets are between 5 and 15 mm in diameter, red or red-brown, euhedral and contain many inclusions usually of quartz. [47]They are all members of the almandine-spessartine solid-solution series. [48]Schist-hosted garnets contain around 75 mol.%, almandine, 11 mol.% spessartine, 8 mol.% pyrope and 2 mol.% andradite. [49]Garnets in pegmatitic and aplite have much higher spessartine contents, generally 60 mol.%, and lower almandine ((mol.%); pyrope and andradite components are negligible. [50]The garnets are very similar in composition to those in other Li pegmatites and aplites from Africa and Thailand. [51]The lack of reaction rims, euhedral shapes and spessartine 50 mol.% suggest that the garnet hosted by pegmatite and aplite were formed by low pressure crystallisation from a Li-H2O-rich pegmatitic fluid.

[52]It is suggested that exsolution of an aqueous phase from the melt complexed available Mn and transported it to the intermediate zone of the Aclare body (Whitworth and Rankin, 1989), raising the Mn concentration locally and permitting garnet crystallisation. [53]Similar models were invoked by Hildreth (1981) and Harrison (1981) to explain the presence of Mn-rich caps to magma chambers and garnets in marginal zones of granite intrusions. [54]These data are also compatible with the P-T-X model developed for the pegmatite by Whitworth (1989), Whitworth and Rankin (1989) and Whitworth (1989). [55]It is unlikely that the garnets were formed by localised partial melting of the crust, but it is important to note that it is still unclear as to whether the pegmatite melt itself was formed by this process and then underwent further evolution (cf Whitworth 1989; Whitworth, in preparation). [56]These data are compatible with magmatic origin for the pegmatite and aplite-hosted garnets.

NS-26: The rheology of faults triggered by the olivine-spinel transformation in Mg2GeO4 and its implications fro the mechanism of deep-focus earthquakes

[1]Several previously reported observations of the anomalous faulting behavior triggered during the a y phase transformation in Mg2GeO4 polycrystals indicated that initiation of faulting is not related to brittle shear fracture. [2](1) The faulting stress is independent of confining pressure, in marked contrast to the pronounced increase with pressure exhibited by brittle failure and predicted by the Mohr-Coulomb fracture criterion (Fig 6a) (Burnley et al., 1991). [3](2) Faulting occurs only in a narrow temperature interval (Green & Burnley 1989, Burnley et al., 1991). [4]At lower temperatures, samples do not transform to spinel (except for the minor production of martensitic lamellae; Burnley & Green 1989) and are ductile and strong. [5]At higher temperatures, samples transform extensively to spinel and are ductile and relatively weak. [6]The mechanical instability correlates with incipient transformation of metastable olivine to spinel. [7](3) No acoustic emissions occur prior to faulting, and a burst of acoustic activity occurs during the stress drop associated with faulting (Fig 4) (Green et al., 1992). [8]This contrasts markedly to the crescendo of acoustic activity that precedes brittle failure due to the formation of Mode I microcracks (Scholz 1990). [9]In addition, anticrack faulting has been observed at 14 GPa during the ß transformation in silicate olivine (Green et al., 1990). [10]This also implies that brittle fracture is not involved in this phenomenon because dilatant (i.e., brittle) processes are impossible at such pressures.

[11]On the other hand, direct evidence for the presence or absence of brittle processes during or after anticrack faulting has been equivocal. [12]Burnley et al., (1991) noted that faults which had slipped extensively (more than 1 mm) exhibited abundant fragments of olivine in the fault zones along with the finer-grained spinel. [13]They speculated that during or after faulting, brittle processes were active and that the pieces of olivine present in fault zones had broken from the borders of the fault and therefore constituted a normal fault gouge. [14]However, Green et al., (1992) noted that the fault 'gouge' (see Fig 12 of Burnley et al., 1991) differs in certain fundamental respects from experimental (Marone & Scholz 1989) and natural (Sammis et al., 1986) fault gouges produced in the brittle regime. [15]Figure 2 shows that comparison directly; anticrack fault 'gouge' has a bimodal particle-size distribution and the grains have rounded, sinuous margins, whereas brittle fault gouge has a fractal particle-size distribution and grains are highly angular. [16]To explain these characteristics, Green et al., (1992) proposed that the olivine fragments in the fault zones were 'carved out' by enhanced local Mode I microanticracking during fault zone propagation and widening (Fig 2c).

[17]The new data presented here imply that the resistance to sliding on faults generated by the anticrack mechanism is not due to a frictional process. [18]First, the sliding resistance depends only weakly on the normal stress on the fault zone, in contrast to the strong dependence of frictional sliding on normal stress universally observed in brittle materials (Fig 6b). [19]Second, an order of magnitude increase in the displacement rate caused the sliding stress to roughly double. [20]Even when friction has a positive rate effect (velocity strengthening), as in granular material, the magnitude of that effect is very much smaller than we observed, on the order of 1% change in strength per order of magnitude change in sliding rate (Marone et al., 1990). [21]Third, the level of acoustic emissions during sliding is only slightly higher than process. [22]Thus, friction is excluded as the process controlling sliding.

[23]To understand the process by which sliding takes place in the spinel-lined fault zones, we compare the results of this study with mechanical data for bulk flow of polycrystalline y-Mg2GeO4. [24]Vaughan & Coe (1981) found that a y-Mg2GeO4 polycrystal with a grain-size of about 2 m exhibited a stress exponent n ~ 2 and concluded that flow probably was dominated by grainboundary sliding. [25]In contrast, Tingle et al., (1991) found that coarser-grained (20-30 m) y-Mg2GeO4 polycrystals flow by dislocation creep, exhibit a stress exponent n ~ 3, and under all conditions are stronger than olivine (e.g., at 1200 K, 1800 MPa and strain-rates of 10-4 and -5 s-1, they measured steady-state flow stresses of 1750 and 800 MPa, respectively). [26]Thus, although the rheology of the fault zones has not been fully characterized, it is not compatible with friction or with the crystalplastic rheology of either olivine or spinel. [27]The most reasonable interpretation is that sliding occurs by grainboundary sliding of the very fine-grained spinel that separates the olivine fragments in the 'gouge' (Figs 2b & c). [28]The pressure- and rate-dependence of the sliding stress are compatible with such a viscous process.

CONCLUSIONS

[29]This investigation confirms that initiation of faulting by the anticrack mechanism in Mg2GeO4 is not related to brittle failure (Burnley et al., 1991) and further shows that sliding after faulting is not controlled by brittle processes. [30]The pressure- and rate-dependence of the sliding stress and the microstructures of the fault zones are consistent with the hypothesis that the rheology of faults triggered by the olivine spinel phase transformation is controlled by grain-boundary sliding in the finegrained spinel of the fault zones. [31]Given that initiation and sliding of such faults are not brittle phenomena, it seems unlikely that fault propagation is a brittle process either. [32]Thus, the physical processes responsible for anticrack faulting in Mg2GeO4 are fundamentally different from those responsible for brittle shear fracture.

[33]These results add to a growing body of evidence that incipient transformation of metastable silicate olivine to ß-phase (or spinel) in lens-shaped microanticracks that organize themselves into throughgoing faults is the mechanism of deep-earthquake faulting. [34]Iidaka & Suetsugu (1992) provided evidence that olivine exists metastably to a depth of at least 500 km in the cold interior of the Pacific lithospheric slab being subducted beneath Japan and Green et al., (1990) showed that anticrack faulting can accompany the ß transformation in (Mg,Fe)2SiO4 at the high pressures at which deep-focus earthquakes occur. [35]Microstructures of the faulted silicate specimen are essentially identical to those of the germanate specimens, and we expect that the rheology and acoustic emissions (seismic) characteristics of faults triggered by the anticrack mechanism during the ß transformation in (Mg,Fe)2SiO4 will be similar. [36]The reader should not conclude, however, that deep faults will slip extensively by superplastic processes after an earthquake. [37]The fine-grained ß-phase or spinel in fault zones probably will coarsen rapidly on a geological time scale and thus leave the nascent fault zones stronger than their untransformed country rock.

NS-27: A footwall system of faults associated with a foreland thrust in Montana

[1]Most of the modelling of thrust systems assumes an initial starting geometry to the faults and generates a sequence that involves foreland propagation of horses to create a duplex style (e.g., Mitra & Boyer 1986). [2]They do not in general allow for, or address the generation of associated minor faults. [3]Wojtal (1986) has given a detailed field description and strain analysis of minor faulting associated with the hanging walls of some Appalachian thrusts, but did not address footwall faults.

[4]An advantage of the clay or sand-box method of fault modelling is that it is possible to start with an unfaulted medium with the faults initiating in the progressive deformation (e.g., Oertel 1965, McClay & Ellis 1987, Reches 1988, Gapais et al., 1991). [5]Reches modelled the initiation and propagation of faults in a clay medium in pure shear. [6]The Gapais et al., (1991) paper illustrates the initiation of faults in an isotropic sand medium in bulk strain conditions ranging from coaxial strain to simple shear. [7]These authors' models were also in bulk plane strain and, since my field example appears to be very close to two-dimensional slip, they form a good basis for comparison. [8]One of the most striking features of the experiment is the way the systems tend to partition the dominant slip from conjugate systems into regimes or domains, but domains that are ephemeral and spatially transitory in terms of active slip. [9]Another important observation is that "arrays of conjugate faults start to develop after about 10% uniform strain and accommodate most of the subsequent deformation" (Gapais et al., 1991). [10]If that observation were to be true in many natural situations, then the assumption made earlier that the array of the major faults mapped represents the main faults that were present throughout the deformation would be reasonable. [11]Both Reches (1988) and Gapais et al., (1991) demonstrated that some secondary faults did form throughout the progressive deformation. [12]The geometric relationship between these and the main faults was not always distinctive enough to tell from geometric criteria alone which were the oldest or youngest, i.e., crosscutting criteria should be used with care.

[13]A final point of comparison with the sand-box models is that the faults in the sand-box experiments typically initiated in conjugate sets in accordance with the Coulomb criterion (acute angle between sets of about 60). [14]The angle between the sets generally increases with progressive deformation, especially in simple shear, in contrast to the pure shear experiments (Gapais et al., 1991, p.149). [15]In our field example, the angles are typically 45-50, which have also been observed in clay experiments (Reches 1988), in contrast to the sand-box experiments. [16]It may well be that the existence of the third slip plane parallel to the bedding constituted an element of planar anisotropy and as such affected the original conjugate angles, as well as the cohesion properties.

[17]While it is not possible in the natural example to everywhere see the original bedding trace to observe the exact amount of rotation of the bedding by fault block rotation, it appears to be low. [18]It turns out that the rotation or not of the bedding-plane trace is one of the best pieces of information or constraints on the restoration. [19]It would be interesting to generate analogue models with a bedding plane slip component.

[20]As Gapais et al., (1991, p 154) point out it is difficult to assess the bulk kinematic strain field, i.e., how much simple shear vs pure shear, from the fault geometries alone. [21]Overall, the fault system I have mapped appears to have a fairly high symmetry generally orthorhombic and a general lack of block rotation. [22]As such, this suggests a predominantly pure shear bulk shortening, with very little effect of 'drag' by the main fault on the geometry of the footwall minor faults.

[23]I believe that it is because of the overall symmetry of the system and general lack of block rotation that the restoration appears to be reasonable and successful. [24]If the faults were less symmetric about the bedding and/or block rotation was more, then a bulk pure shear restoration might not be effective different boundary conditions would be required and the assumption of reversibility of sequences inappropriate. [25]This would make it far less tractable.

CONCLUSIONS

[26]By combining and synthesizing information gathered from several different sources of data, it is possible to model an evolution of a system of thrust faults accommodating a considerable amount of horizontal shortening. [27]Domainal slip systems appear to be an effective method of achieving bulk shortening off the main fault. [28]In this particular field example most of the off-the-main fault deformation is in the footwall and appears very similar to a recent seismic example.

[29]While there are obviously some limitations and shortcomings to analogue simulation by palinspastically restoring a field-based block model, it does demonstrate in a general way the feasibility of achieving bulk strains by discrete slip between blocks, demonstrate the importance of slip partitioning and sequencing in domains and makes another basis for comparison with clay and sandbox models.

[30]This well-exposed example demonstrates the self-similar nature of the fault system over at least a certain Size domain. [31]The lack of obvious physical controls on the Size distribution of the faults suggests that the distribution may be predominantly dictated by kinematic constraints (cf King 1983, Gapais et al., 1991). [32]This field example provides a good example for comparison with models that have been proposed to explain earthquake magnitudes, 'b' values and total fault budgets (King 1983, Scholz & Cowie 1990, Marrett & Allmendinger 1991, Walsh & Watterson 1992).

NS-28: The interplay between fluids, folds and thrusts during the deformation of a sedimentary succession

[1]The composite crystal veins discussed earlier provide evidence to indicate that in some situations bedding plane-parallel thrusts may be initiated or reactivated by high fluid pressures which jack the beds apart by hydrofracture as they slide past each other.

[2]It is suggested that once the hydraulic fracture has occurred, the resulting lens of fluid will be driven along the bedding plane in a manner analogous to an edge dislocation being driven along a lattice plane in a crystal subjected to a shear stress. [3]As the fluid lens is driven away from the site of initial hydraulic fracturing, bedding-plane slip ceases at this locality and the system locks up [4]Reshear will occur only when the deformation processes have re-established the fluid pressure necessary to regenerate hydraulic fracture. [5]Thus movement of the thrust will occur in a stick-slip manner.

[6]The movement of tectonically driven fluids along a fracture system in a deforming accretionary complex has been considered by Vrolijk (1987). [7]On the basis of a fluid inclusion study he was able to demonstrate that there was a 20-45% drop in fluid pressure during the growth of quartz in syntectonic extensional veins. [8]He argues that this pressure drop is probably the result of the relatively rapid expulsion of fluids along an interconnected fracture network.

[9]It has been argued by Price & Cosgrove (1990, pp 367-384) that like thrusts, large folds are likely to be initiated at local sites of hydraulic fracture that form parallel to bedding in areas of relatively low bedding-plane cohesion. [10]At these locations a lens of fluid will form along the bedding plane which jacks the beds apart, reducing the effective stress across the bedding plane to zero.

[11]As these folds amplify by the process of flexural-slip, bedding-plane slip and fluid flow will occur. [12]Multiple layers of crystal fibres found on bedding planes on the limbs of such fold indicate that the slip occurred in a series of pulses associated with the build up and dissipation of fluid pressures. [13]During flexural-slip folding bedding-plane slip is greatest at the inflection point and decreases to zero at the hinge. [1]It is suggested that the process of bedding-plane slip which accompanies flexural-slip folding is directly analogous to slip on thrusts discussed above, i.e., bedding-plane slip occurs in a series of pulses (stick-slip) and during each pulse fluid is ejected from the area of local slip towards the hinges. [15]Bedding-plane slip during folding could thus produce a local migration of fluids within the fold from the limbs to the hinge regions.

[16]It follows that during folding there will be a local migration of fluids within the fold from the limbs to the hinges associated with episodes of bedding-plane slip, together with a migration of fluid in and out of the fold associated with the stress gradients defined by equation (1) and illustrated in Fig 6(e).

[17]If the concept of stick-slip movement along the bedding planes during flexural-slip folding is valid (and the multiple crystal fibre horizons found on folded bedding planes and formed during the folding indicate that it is) then the implication is that the folds amplify in a series of pulses rather than in a smooth and gradual manner. [18]Immediately after an increment of amplification a stress gradient would be established and fluid would migrate either into or out of the fold depending on the limb dip, (Fig 6e). [19]The gradients and associated migration would gradually decay until the next increment of fold amplification reestablished a stress gradient and the process was repeated. [20]It is not difficult to envisage the formation of several cross-cutting generations of hydraulic fractures and veins as these pulses of fluid flow into and out of the fold.

CONCLUSIONS

[21]The evidence from the study of composite calcite veins formed parallel to bedding during the thrusting of the Wenlock shales north of Llangollen, North Wales, indicates that movement occurred in a series of pulses and was associated with high fluid pressures (Y1).

[22]Composite horizons of slickensides found on the limbs of large box-folds indicates that the bedding-plane stick that occurs during their formation also occurred in a similar, stick-slip manner. [23]In addition the stress distribution within and around an amplifying box-fold show that initially fluids will be drawn into the structure but at some critical stage in its amplification will begin to be expelled.

[24]Thus in a deforming sedimentary succession both folding and thrusting can be expected to cause episodic variations in pore pressure and stress.

[25]The expulsion of fluids along thrusts and out of folds as they lock up may help to generate new structures in the adjacent relatively undeformed parts of the succession.

NS-29: Constant bed-length folding: three-dimensional geometrical implications

[1]Isotrend line analysis is capable of detecting fold surfac8e morphologies which require bed stretching for their development. [2]This simple technique can be used to highlight areas of probable bed-plane strain or faulting.

[3]Caution is advocated when drawing conclusions from isotrend line patterns. [4]Although isometric deformation implies developable fold geometries, the converse is not necessarily true. [5]Cylindrical folds are examples of developable surfaces that could form from a variety of mechanisms including those of a non-isometric nature. [6]Also a homogeneous flattening strain imposed on any developable surface will modify its shape but not its developable character. [7]Although only a few structure maps have so far been subjected to the analysis described above, it is already apparent that bed-strain is normally involved in folding. [8]In this respect it is interesting to note that hydrocarbon entrapping fold structures with 'closure' cannot form by constant bed-length folding. [9]In a strict sense, line-length balancing of cross-sections is a theoretically unsound technique even in cases where the folds involved are isometric.

[10]Although the isometric folding model is an idealize one, its predictions may be of relevance, at least in a qualitative way, to sequences in which a parallel folding style is developed. [11]The model requires a careful consideration of curvature which has important implications for the problems of refolded folds (Stauffer 1988, Lisle et al., 1990), salt domes, subducting plates (Bayly 1982) and the nature of the terminations of folds (Wilson 1967, Webb & Lawrence 1986).

NS-30: Three-dimensional finite strain from crinoid ossicles

[1]The methods presented in this paper are simple extensions of well established strain analysis techniques. [2]When applied to crinoid ossicles from the Wildhorn Nappe, the methods produce results that are internally consistent and compatible with those from other strain analysis techniques. [3]The significant scatter and probable error ranges of the calculated strain ellipsoids are effects of the low strains in these samples, and would presumably be reduced at higher strain states.

[4]Although the techniques as described are applicable to rocks in which the crinoid ossicles are approximately randomly oriented, so that the different cuts of Fig 1 are present in any thin section, the methods can be combined to measure three-dimensional finite strain when the ossicles are preferentially oriented. [5]For example, if the crinoid disks lie approximately parallel to bedding (c-axes orthogonal to bedding), three perpendicular thin sections should be cut so that one is parallel to bedding. [6]The two-dimensional strain in this section is measured using Rf/ analysis of the circular and elliptical cuts, and the other two sections, both oriented roughly parallel to the cylinder axes, are analyzed with the angular shear strain method on the rectangular and sub-rectangular cuts. [7]The results from the three sections are then combined as usual to calculate the finite strain ellipsoid. [8]This technique will not work if the ossicles are all oriented identically, as the angular shear strain analysis will yield only one point on the Breddin graph; some variation in orientation is required. [9]As the spread in orientations increases, the accuracy of the Breddin graph curve fitting also increases.

[10]The methods described here have several advantages over the three-dimensional technique developed by Spratt (1987). [11]First, knowledge of the original shape of the ossicles, i.e., whether they had circular or elliptical cross-sections, is not required. [12]The Rf/ analysis is applicable in either case. [13]Second, the orientations of the ossicle c-axes do not need to be determined in order to remove the effects of oblique cuts through the crinoid disks. [14]Third, the flat-stage technique for determining the c-axis orientations (Spratt 1987) is ambiguous for ossicles with large height-to-diameter ratios. [15]Spratt showed that the c-axis cannot be determined uniquely if it is inclined between 26 and 64 to the pole of the thin section, and that since the elliptical cuts in her samples are always inclined at an angle of less than 24, the method is useful. [16]However, for ossicles with height-to-diameter ratios greater than 0.5:1, the c-axis orientations cannot be determined unambiguously. [17]In the case of the Wildhorn Nappe samples, the elliptical cuts may have c-axes inclined up to 65 from the pole of the thin section, and the flat-stage technique is unusable. [18]The Rf/ and angular shear strain methods, on the other hand, are not bound by any of these restrictions, and can be applied easily to a wide range of crinoid-bearing rocks.

Appendix E-4

Pakistani Geology RA Discussions used in the study

PAK-01: A-Type granites of Warsak, Khyber Agency, N. Pakistan: Rift-related acid magmatism in the Indian Plate

[1]Granites are found in almost all the major tectonic settings, including mid-oceanic ridges, island arcs, continental margins, and within plates (see Pearce et al., 1984 for an exhaustive review). [2]The granite magmatism in the Peshawar plain, on the basis of its geological position at the northern margin of the Indian plate, can be of several different origins. [3]Some possibilities are: 1) magmatism in Andean-type continental margin; the Tethys ocean subducted southward below the Indian plate, producing calc-alkaline granitic plutons of granitic composition similar to those formed in the Kohistan and Asian plates due to northward subduction of the Tethys (see Petterson and Windley, 1985; Le Fort et al., 1983); 2) collision granites, formed by thickening of the crust of the Indian plate after its collision with Kohistan-Karakoram. [4]Such granites are reported from the northern margin of the Indian plate such as the famous Mansulu granite of Nepal (Le Fort, 1981). [5]3) Within-plate A-type granitic magmatism, related with an episode of rifting, which could be simultaneous with the India-Kohistan collision (Kempe & Jan, 1980; Butt et al., 1980), or earlier (Le Bas et al., 1986; Mian, 1987).

[6]Obviously, for a precise determination of tectonic setting of magma generation for the Warsak and other granites in the Peshawar plain (Such as Ambela, Malakand, Shewa Shahbazgarhi and Tarbela; see Kempe & Jan, 1980, for the basis of correlation) a two-fold approach is required: firstly the chemistry of granites, in particular in terms of incompatible trace elements, needs evaluation in order to ascertain the type of magma. [7]Secondly, radiometric age data are required in order to determine relationship between various granites in the context of changing plate tectonic history of the Indian plate.

[8]The radiometric age dating is out of scope of this study, but it is now possible to assign a Late Palaeozoic age to the Warsak granites on the basis of pre-established correlation with the Ambela granite and the Shewa-Shabazgarhi for which both radiometric and stratigraphic dates of this age are now available (Le Bas et al., 1987; S.R. Khan et al., 1990).

[9]This, when combined with the A-type nature of the Warsak granites, one is compelled to relate the granite magmatism of the Peshawar plain with the famous Late Palaeozoic fragmentation of the Gondwana and separation of India. [10]There is a possibility that the deformed two-mica granite of Warsak is equivalent to the acid volcanic event such as that documented by S.R. Khan et al., (1990) from the Carboniferrous Jaffar Kandao Formation from the Swabi area, while the aegirine-riebeckite bearing granites are equivalent to Late Palaezoic-Early Triassic Ambela granite (Rafiq, 1988).

[11]It has to be noted that Kempe (1978) pointed out the possibility of basic extrusives in the Warsak area. [12]The close association of the Warsak granites and the basic rocks is a characteristic feature of the Peshawar plain failed rift, as described by S.R. Khan et al., (1990) and Jan & Karim (1990).

PAK-02: Heavy mineral analysis of the molasse sediments, Trans-Indus ranges, Kohat, Pakistan

[1]Although the heavy mineral assemblage appears fairly similar across the molasse succession, there is a marked change in the relative abundance of different minerals at various stratigraphic levels. [2]Also a number of new minerals appear in different formations, e.g., amphibole, pyroxene, staurolite and sillimanite occur in the Siwalik Group, but are absent in the Rawalpindi Group. [3]In essence, the sediments of the Siwalik Group, particularly those of the Shakardarra and Indus Conglomerate formations, are characterized by the appearance of minerals derived from high-grade metamorphic and igneous rocks.

[4]The introduction of blue-green amphibole during Miocene times in the molasse sediments of Potwar and the Surghar range (Abid et al., 1983; Johnson et al., 1985), is rather unique to this part of the Himalayan foreland basin. [5]Elsewhere, for instance in the part of the foreland basin exposed in India, there is a complete absence of amphibole in the molasse sediments (Chaudhri, 1971, 1972; Raiverman et al., 1983). [6]Indeed, the heavy-mineral suite of the molasse sediments in India is much different from that found in the molasse sediments of the present study (Fig. 5). [7]In the Indian molasse sediments, zircon, garnet, tourmaline and staurolite constitute the bulk of the heavy- mineral fraction with subordinate amounts of epidote (Chaudhri, 1972). [8]Hornblende and pyroxene are either not present (Chaudhri, 1972) or, if found, are fairly uniformly distributed (Raiverman et al., 1983) across the succession. [9]These differences in the heavy minerals in the Kohat-Potwar area and Indian part of the foreland-basin suggest different provenance and different catchement areas for the river systems. [10]The molasse sediments in the Indian part of the foreland-basin were probably deposited by a river system similar in source to the present-day Ganges River (Fig. 5), but very different from that of the palaeo-Indus River.

[11]Of all the heavy minerals found in the molasse sediments in the Kohat foreland basin, garnet and amphibole are particularly important because of their abundance in particular parts of the Himalayan orogenic belt. [12]For instance, amphibole is amongst the major constituent minerals of the metabasic igneous rocks in the Kohistan island arc terrain, which is now accreted with the Indian plate at its northern margin (Tahirkheli et al., 1979; Coward et al., 1986). [13]Garnet, on the other hand, is more common in the basement metamorphic rocks in the Indian plate than in the Kohistan arc.

[14]A greater abundance of garnet of almandine composition in the Rawalpindi Group, and its consistent presence in the entire molasse succession, suggests that the deep- seated Indian- plate basement rocks were exposed even prior to the onset of deposition in the foreland basin, and were the main source of the detrital material throughout the depositional history of the basin. [15]As far as the contribution from the Kohistan arc sequence is concerned, it can be monitored on the basis of both amphibole and garnet (relatively richer in pyrope component than that of the Indian plate). [16]These two minerals, however, do not appear simultaneously; amphibole starts appearing at the base of the Shakardarra Formation, whereas the pyrope-rich garnet is found mainly in the Indus Conglomerate Formation. [17]This may be due to differences in the abundances of these minerals at different stratigraphic levels in the Kohistan arc sequence.

[18]Amphibole in the Kohistan arc is characteristically found in the intermediate to shallow level metabasic rocks, while the garnet-bearing rocks are restricted to intermediate to deep-crustal levels (e.g., Kamila amphibolite and the Jijal Complex).

[19]Appearance of the amphibole at the base of the Shakardarra Formation would record a metamorphic event responsible for the uplift and exposure of the upper to intermediate levels of the Kohistan arc crust. [20]The appearance of pyrope-rich garnet in the uppermost molasse succession suggests exposure of the basal arc crust in Kohistan much later than the shallow to intermediate crustal levels.

PAK-03: Shallow marine sediments of the Patala Formation of Paleocene age, Kohat area, Pakistan

[1]The Patala Formation consists of abundant fauna such as foraminifers, mollusks, and ostracodes (Shah, 1977) which evidently suggests that these strata were deposited in marine environments. [2]Locally, the formation predominantly consists of clastic sediments ranging from conglomerate/pebbly sandstone to fine-grained sandstone, siltstone and shale. [3]Limestone and marl beds are also present in certain horizons of the formation.

[4]The pebbles in strata of basal portion of the formation are in general rounded. [5]Microscopic studies of these sandstones reveal the dominance of quartz and chert grains with subordinate proportions of feldspar and other minerals. [6]These grains in general are texturally mature.

[7]This textural and to a large extent compositional maturity of the pebbly sandstone beds of facies PF1 as well as composite bedding in lower portion suggests their deposition under high energy conditions (cf. Folk, 1974; Kumar & Sanders, 1976; Cotter, 1983).

[8]The upper portion of facies PF1 consists of lenticular, coarse pebbly and non-pebbly medium- grained sandstone beds which are interbedded with shale beds.

[9]This points to the interchange of quiet and high energy intervals (cf. Reineck & Singh, 1972; Kreisa, 1981) thus suggesting seaward deposition of these strata compared to the lower portion of facies PF1.

[10]There is a possibility that the conditions of deposition fluctuated briefly during the deposition of facies PF2 from purely clastic to alternating between clastic and non-clastic environments locally. [11]However, the limestone beds in this facies may also suggest that limestone was being deposited in a nearby location and overpassing storms may have eroded these sediments and carried to the location of deposition of facies PF2 which was depositing in a dominantly clastic regime. [12]The overlying shale and siltstones of facies PF3 were deposited more seaward of facies PF1 and PF2 in an offshore setting. [13]Thin marl interbeds of facies PF4 appear to be distal storm beds (cf. De Raaf et al., 1977; Brenchley, 1985) in an offshore setting and the uppermost portion of the formation consists mainly of shale with scarce thin marl beds suggesting it to be further offshore in origin. [14]The absence of well developed shoreface facies and rapid transition from foreshore or upper shoreface to offshore sediments suggests a narrow shelf with relatively steep gradient in Kohat area during deposition of the Patala Formation.

[15]The sediments of this formation are not bioturbated. [16]The conditions for survival of organisms were hospitable during deposition of these strata as is evident from the presence of abundant body fossils (Shah, 1977).

[17]The absence of bioturbation could then be considered due to fast rates of sedimentation. [18]The organisms were unable to churn down the fast depositing sediments.

[19]From the above discussion, it is clear that the Patala Formation in Kohat area generally exhibits fining upward sequence (Fig. 36). [20]This fining upward trend is most probably related to the continuous deepening environments of deposition during sea transgression.

[21]Rashid et al., (1988) mistakenly considered the overturned strata (A.A.K. Ghauri & Obaid-ur-Rahman, personal communication, 1988) of the Patala Formation at Kohat Pass as a normal sequence. [22]Consequently, strata of the basal facies PF1 makes top of their lithologic column and uppermost facies PF4 in this article makes their basal strata.

[23]Based on their lithologic column Rashid et al., (1988) had suggested a prograding upward sequence for the Patala Formation. [24]In reality the sequence is transgressive upward.

[25]The Patala Formation depicts lateral variations in lithology. [26]The most pro- nounced change, comparing with lithology of the formation in Kohat area, is the presence of coal seams of economic value locally in Dandot area of the Salt Range (Shah, 1977).

[27]Whereas no coal seam is reported in the literature from the study area and surrounding localities. [28]No direct evidence of stream entrance in the studied sections is present.

[29]The sediments of these localities may have been transported by longshore currents and/or brought in by flashy streams with no delta consisting of marshes and swamp build-ups.

PAK-04: Structures in the hangingwall of the main boundary thrust: post-folding thrust and normal faults from the Kotal-Pass area, Kohat range, N. Pakistan

[1]Whereas the recognition of faults in the Kotal Pass area has been a relatively simple matter of observation, owing mainly to dramatically good exposures and well established stratigraphy (Gardezi et al., 1976; Ghauri et al., 1983), the assessment about their nature is not that straightforward. [2]The shallowly north-dipping fault (Fig. 3) at the contact between the Lockhart and the Kawagarh Formations was apparently reverse in its sense of movement, as it brought near-horizontal strata of the Lockhart Formation probably from the core of the box-shaped syncline to lie on top of the steeply northward dipping strata of the Kawagarh Formation in the southeastern limb of the syncline. [3]This fault owes its initiation probably to tight folding in area which resulted in south-verging out-of-the-syncline thrusting. [4]Late stage movement along this fault transported the Paleocene strata southward to lie upon Mesozoic succession as tectonic blocks.

[5]Our interpretation about the initiation and subsequent movement on these south-verging fault structures have been portrayed in (Fig. 7a,b), together with their relationship to their host fold structure.

[6]We, however, do not believe in the entirely reverse sense of movement of the faults at the base of the southward projecting tectonic blocks comprising Paleocene strata.

[7]The shallow, southward dip of these faults, together with a considerable displacement of younger strata on top of the steeply dipping Mesozoic succession would favour a normal sense of movement on these faults.

[8]We interpret that southward, up-dip movement of the Paleocene strata out from the core of the synclinal fold resulted in an abnormal uplift of the Kotal Pass area (Fig. 7c). [9]This led to initiation of southward dipping normal faults, along which there was a gravitational collapse of the uplifted Paleocene strata. [10]Abundance of fault breccia associated with the fault planes suggests a near- surface level of these late stage normal faults.

CONCLUSIONS

[11]The Kotal Pass area of the Kohat range shows evidence of latest structures associated with the MBT zone. [12]The early-stage thrust and fold structures in the hangingwall of the MBT resulted in the formation of box-shaped folds with tight overturned limbs. [13]One such syncline at Kotal Pass is characterized by several south-verging out-of-the syncline-thrust faults, which resulted in an abnormal uplift of the Kotal Pass area. [14]This was compensated by the development of southward dipping shallow normal faults, along which there was a gravitational collapse of the uplifted Paleocene strata.

PAK-05: The Tora Tigga Complex, Southern Dir, NW Pakistan: an example of mafic-ultramafic rocks in the bottom of an island arc

[1]Systematic variation in chemistry from ultramafic rocks to metagabbros through hornblendites suggests that the Tora Tigga rocks are derived from a basic magma by fractional crystallization.

[2]There are strong reasons to think that fractionation was controlled by early separation of olivine + minor chromite, followed by two pyroxenes, and hornblende. [3]This led to an enrichment of SiO_2, Al_2O_3, alkalis, Sr, Zr, and depletion of MgO, FeO*, Cr, Ni, V and Co in the melt that produced gabbroic rocks.

[4]Textural details suggest a replacement or metamorphic origin for much of the hornblende in the complex. [5]The Na + K vs Al^{iv} plots of the hornblende in five hornblendites fall in the field of metamorphic rather than igneous huornblendes from the St. Anthony complex (Jamieson, 1981). [6]It cannot, however, be ascertained that the hornblendites are metasomatic and chemically changed, because they show systematic chemical variations with the rest of the rocks. [7]This discrepancy between textural details and chemistry can be explained in a number of ways: (1) The hornblendites and much of hornblende in the remaining rocks are igneous but recrystallized during metamorphism, (2) There are igneous as well as metamorphic hornblendes, and the chemical data are not sufficient to distinguish the origin of the amphiboles in the complex.

[8]We are unaware of the occurrence of such large bodies of hornblendites in "alpine" or stratiform complexes. [9]However, large bodies of hornbldnee-rich gabbros and diorites occur elsewhere in the world.

[10]In the plutonic blocks from Lesser Antilles island arc (Arculus & Wills, 1980), modal hornblende reaches up to 70%. [11]Garcia (1982) has reported a gabbro forming the basal part of a Cretaceous island arc in SW Oregon. [12]This body is essentially composed of hornblende (about 50%) and calcic plagioclase, and is therefore similar to some of the plagioclase hornblendites of Tora Tigga. [13]Hornblende, generally, is abundant and hornblendites are more common in the Alaskan-type complexes (Taylor, 1967) confined to gabbroic terrains.

[14]However, a complete lack of hornblende-magnetite clinopyroxenites, abundance of orthopyroxene, and the low Al_2O_3 content of the clinopyroxene (deduced from the whole rock analyses of clinopyroxene-rich rocks) do not typify the Tora Tigga complex as Alaskan-type.

[15]The Duke Island Alaskan-type ultramafic complex contains variable amounts of post-cumulus replacive-type hornblende in ultramafic rocks, as well as marginal hornblendites, and hornblende-Ca-rich plagioclase pegmatite swarms. [16]The hornblendites are variable in grain-size and pegmatitic varieties may cut the others (Irvine, 1974). [17]In these respects the Duke Island and Tora Tigga complexes have a close resemblance.

[18]Irvine suggested that the hornblende was derived from an intercumulus magma that was rich in water and different from the settled minerals. [19]The hornblendites and hornblende pegmatites were produced from this liquid.

[20]Such a situation may also have existed in Tora Tigga, the final manifestation of which may be the plagiogranite dykes that are invariably associated with the hornblendites. [21]The production of so much hornblende and hornblendites from intercumulus liquid would require a larger quantity of ultramafic rocks in Tora Tigga. [22]It is possible that ultramafic rocks are more abundant at depth, since the base of the complex is not exposed.

[23]In conclusion, it is likely that the hornblendites and at least some hornblende in the remaining rocks are of igneous origin. [24]The quantity of hornblende, however, may have increased during metamorphism. [25]Much of the hgornblende in metagabbros, for example, clearly has grown at the expense of pyroxene during amphibolite facies metamorphism.

[26]The Tora Tigga ultramafic rocks have closer similarities with stratiform than tectonized ultramafic rocks, and the metagabbros have island arc-type chemical characteristics. [27]Their rapidly decreasing FeO*, TiO, V and increasing SiO_2, Al_2O_3 contents with differentiation suggest that they may be derived from a calc-alkaline magma.

[28]The Chilas complex, forming the back-bone of the Kohistan arc, is also considered calc-alkaline (Jan, 1980; Bard, 1983). [29]In a number of places in the amphibolite belt, there are partially amphibolitized bodies of plutonic rocks identical to those of the Chilas complex; some of these are located not far from Tora Tigga.

[30]Thus, and as already suggested on the basis of petrographic similarities, the Tora Tigga complex may be related to the Chilas complex of Khan et al., (1989).

[31]Luhr & Carmichael (1985) regard high-alumina basalts too depleted in MgO, Ni, and Cr to have been generated by partial melting of mantle, and that significant fractionation of olivine, augite, plagioclase and spinel has probably played a role in their evolution from primitive basalt magma.

[32]The Tora Tigga and (parts of) Chilas complexes may represent such an example of fractionated minerals in the base of an island arc.

PAK-06: Petrology of the Shewa-Shabazgarhi complex, Mardan, North Pakistan

[1]It is obvious from the field relationship, petrography and chemistry of the Shewa-Shahbazgarhi complex that the basic and acidic rocks existing more than one independent suites in the sense that their genetics belong to different ages, source regions and crystallization histories. [2]The basic rocks including metagabbro, metadolerite and the basic dykes intruding the metagabbro at Budsari represent one major suite of rocks. [3]Whereas the acidic rocks including microporphyry, aegirine-riebeckite porphyry, riebeckite gneiss and porphyritic microgranite together with the acidic dykes (i.e., at Budsari) represent the other major cognate suite. [4]On many of the discrimination diagrams, the basic suite indicates characters of tholeiitic flood basalts and the acidic ones show characters of alkaline to peralkaline rocks; both the groups, however, unanimously reflect emplacement in continental environment.

[5]The major element chemistry indicates crystal fractionation (and possibly partial melting of the same source for various rock types) and the control of clinopyroxene, plagioclase and magnetite on the liquidus being responsible for producing the evolutionary trend of the basic rocks. [6]Presently, the basic rocks contain amphibole, plagioclase and magnetite as their important constituents. [7]As stated earlier, the trace element chemistry oppose the role of amphibole as one of the fractionating phases. [8]The texture of the metagabbro and metadolerite clearly reflects the formation of the bluish-green to brown amphibole of ferro-hornblende composition (Hamidullah and Ahmad in prep.) at the expense of plagioclase and magnetite. [9]Clinopyroxene is missing from majority of the sections of metagabbro and metadolerite and whereever it is present, it occurs as relics in a minor proportion but indicates transformation to amphibole. [10]All such features indicate the prevalence of lower amphibolite facies environment for a considerable time in basic rocks (see Miyashiro, 1973). [11]Also in basic rocks, brown biotite and epidote both occur in close association indicating development after hornblende and plagioclase.

[12]This feature can be attributed to retrogression and the possible prevalence of epidote-amphibolite facies environment subsequent to the pre-existing lower amphibolite facies conditions. [13]The occasional replacement of biotite with chlorite in metagabbro signify further retrogression to greenschist facies.

[14]The basic dykes generally correspond with metagabbro and metadolerite on the basis of mineralogy and chemistry. [15]These dykes can be therefore considered differentiates of the same magma which has given rise to metagabbro and metadolerite.

[16]A completely different evolutionary trend is reflected by the major element chemistry of the acidic rocks. [17]A dominant feldspar (plagioclase, K-feldspar) fractionation is shown by these data and hornblende fractionation by the Zr vs D.I. plots (cf. Pearce & Norry, 1979). [18]Plagioclase, orthoclase and perthite phenocrysts/ porphyroblasts/ porphyroclasts occur in all the acidic rocks and a plagioclase megacryst of 1 cm diameter, retaining igneous signatures has been noticed in aegirine-riebeckite porphyry (Ahmad, 1986), confirming plagioclase fractionation. [19]No igneous hornblende has been however, identified in the acidic rocks but a considerable amount of post-emplacement greenish-brown hornblende replaced by blue-green riebeckite and biotite occurs in riebeckite gneiss and aegirine-riebeckite porphyry. [20]Biotite of greenish brown colour, also replaced by riebeckite and epidote, is noticed in these rocks.

[21]Therefore, any igneous hornblende if present seems to have been consumed during the formation of ferromagnesium minerals in the latter events. [22]The textural relationship of the minerals present thus indicates an evolutionary sequence of metamorphic events encompassing amphibolite facies conditions (greenish-brown hornblende), followed by retrogression (development of biotite after greenish-brown hornblende and epidote after biotite) into epidote-amphibolite or upper greenschist facies. [23]The development of riebeckite after greenish-brown hornblende and biotite, as well as after aegirine, in riebeckite gneiss and aegirine riebeckite porphyry (see Ahmad, 1986), can be attributed to a second phase of relatively high grade metamorphism (blue-green hornblende is rare in green-schist facies; Miyashiro 1973, p.254) or Na-metasomatism during the emplacement of the latter phases, i.e., porphyritic microgranite and acidic dykes.

[24]On the basis of chemical data, the microporphyry closely corresponds with other acidic rocks (Figs. 7-10).

[25]This observation is in accord with the gradational contact of the microporphyry with aegirine-riebeckite porphyry at Machi and Taja (Fig. 2; Ahmad, 1986). [26]At Budsari, however, the microporphyry has been reported to be older than the metagabbro (Noor Jehan, 1985). [27]The term microporphyry has been in fact invariably used for the fine-grained splintery and well jointed rocks with variable colour from earthy-white through greysh-green to slaty-black (see Ahmad, 1986, p.18).

[28]A careful examination unravels that in certain sections the Budsari microporphyry shows volcanic flow phenomenon but in other sections a considerable amount of graphite is present; a feature indicating it to be a combination of volcanic and sedimentary material and a possible member of the Sawabi-Chamla group. [29]Unfortunately, all the chemical data presented on the variation diagrams belong to the microporphyries of the Machi section. [30]This microporphyry thus seems to be a differentiate of the aegirine-riebeckite porphyry.

[31]In such a case the origin of the microporphyry at Budsari needs to be re-considered for detailed investigation.

[32]The most significant feature of the rocks of Shewa-Shabazgarhi complex is the severe impact of cataclasis in acidic rocks, particularly in microporphyry and porphyritic microgranite. [33]Fluxion structure and mortar texture superimposed on "volcanic flow" type of texture, broken and elongated grains of quartz and feldspar, broken aggregates of these large crystals, the laminated groundmass indicating abrupt variation in grain size and in some cases indications of recrystallization and neo-mineralization, all provide ample evidence of this phenomenon. [34]On the basis of grain size, presence and absence of fluxion structure and the comparison of cataclasis with neo- mineralization and recrystallization the cataclasized portions of the affected rocks were classified following the scheme of Higgins (1971) and Bell & Etheridge (1973). [35]The various varieties identified are structureless cataclasite, pseudo-tachylite, proto-mylonite, mylonite, ultra-mylonite and cataclasite.

[36]Ahmad (1986) has attributed the formation of certain new minerals, including biotite, epidote, aegirine, riebeckite and sillimanite in the aegirine-riebeckite porphyry and riebeckite gneiss to the mobility of elements (release of alkalies and concentration of Al_2O_3) during cataclasis. [37]Cataclasis is however, generally referred to as brittle deformation at shallow levels of low temperature with a minimum degree of recrystallization.

[38]Therefore, as mentioned earlier, the growth of new minerals in these rocks may be considered solely a metamorphic or metamorphic-cum-metasomatic phenomenon. [39]In this context Na-metasomatism can be considered a factor in the development of alkali minerals, like aegirine and riebeckite.

[40]One of the confusing aspects of the Shewa-Shabazgarhi complex is the nomenclature of various rocks suggested by various workers (i.e., Martin et al., 1962; Chaudhry & Shams, 1983, Waleed & Bakhtiar, 1980; Noor Jehan, 1985; Ahmad, 1986). [41]These authors have classified the rocks considering only a particular aspect among mineralogy, grain size, metamorphism and cataclasis etc.

[42]In fact, the intensities of various phenomenon, which have played roles in the evolution of the Shewa-Shabazgarhi complex, vary from place to place and thus granting different appearance to one and the same rock at different places in a single outcrop, or vice-versa. [43]For example, the cataclasized porphyritic microgranite and microporphyry appear similar, whereas, the cataclasized porphyritic microgranite looks very different from its uncataclasized counterpart, at the western edge of Budsari outcrop. [44]Also as mentioned earlier, the porphyritic microgranite has characters which are more representative of volcanic rather than plutonic origin, e.g., layering, "pillar type" structure due to the development of mural joints, phenocryst- groundmass relation, groundmass grain size and volcanic flow texture (Figs. 3,6). [45]In fact, the superimposition of metamorphism and cataclasis has overshadowed its volcanic appearance.

[46]Therefore, considering all the genetic and mineralogical aspects a careful examination is needed to re-classify all rocks of the Shewa Shabazgarhi complex.

[47]Several theories have been proposed about the generation of magma(s) for the Shewa-Shabazgarhi complex and in general for the alkaline igneous complexes around the Peshawar basin (cf. Fig.1), among which are the differentiation theory of Kempe (1973), the intra-continental subduction theory of Powell & Conaghan (1973), the vale-rift zone theory of Kempe & Jan (1980), the Indo-Pak subduction-related theory of Chaudhry & Shams (1983) and the theory of a Pre-Himalayan subduction of Noor Jehan (1985).

[48]The present study has confirmed that both the basic and acidic rocks are of continental rift type. [49]Comparable complexes have been dated as old as 315 Ma (Malakand granite; Zeitler, 1988) and 250 Ma (Koga corbonatite; LeBas et al., 1987) and thus the Shewa-Shabazgarhi complex also seems to be much older than the collision date along MMT (i.e 55 ma; Coward et al., 1987; Hamidullah & Onstot in prep.) and therefore, a product of some Pre-Himalayan tectonism.

[50]It is not very clear whether the individual rock types are solely the products of differentiation in separate basic and acidic large magmatic chambers or batch partial melting of the source rock has also played a role in the production of the evolutionary trends at Shewa-Shabazgarhi.

[51]Rare earth and isotopic studies are needed to resolve these issues.

[52]It is appealing however to consider, that the generation of the basic magma(s) at deep crustal or upper mantle level due to rifting has provoked the melting of the upper crust to produce acidic magma(s) for rocks younger than the metagabbro and matadolerite. [53]The acidic magma which has given rise to the igneous portion of the microporphyry at Budsari (i.e., older than the basic rocks) may be considered then, the product of an earliest rift-related anataxis probably at higher levels than that responsible for the later acidic types.

CONCLUSIONS

[54]1. Rocks of the Shewa-Shabazgarhi complex are the product of basic and acidic magmatism/volcanism initiated as a result of rifting of the Indo-Pak continental crust.

[55]2. The basic rocks, including metagabbro, metadolerite and other basic dykes are derived from a tholeiitic flood basalt type of magma, whereas the acidic rocks including microporphyry, riebeckite gneiss, aegirine-riebeckite porphyry and porphyritic microgranite are derived from a magma of alkaline to peralkaline characters.

[56]3. During igneous crystallization clinopyroxene, plagioclase and magnetite were the dominant fractionating phases on the liquidus in the basic rocks, whereas, feldspar and amphibole were the dominant fractionating phases on the liquidus in the acidic rocks.

[57]4. The existing mineral assemblages both in the basic and acidic rocks indicate the prevalence of amphibolite facies metamorphism followed by retrogression.

[58]5. Cataclasis followed metamorphism in the acidic rocks.

PAK-07: Sodic pyroxenes and amphiboles from Koga syenites of Ambela granitic complex, N.W.F.P., Pakistan

[1]The Na-pyriboles developed in alkaline igneous and metamorphic rocks have compositions related to their host rocks, those developed during fenitization depend not only on host rocks composition but also on the composition of fenitizing fluids emanating from alkaline igneous rocks. [2]Amongst the pyriboles magmatic Na-pyroxene shows various trends of fractionation during emplacement of alkaline rocks.

[3]These trends, given by different authors (Fig. 5), show the enrichment of acmitic component during the fractionation.

[4]Similar trend is present in magmatic Na-pyroxene in Koga rocks. [5]However, Na- pyroxene in fenitized syenites and granites of Koga show reverse trends which are from acmitic to diopsidic and/or hedenburgitic component.

[6]It is suggested that there are two types of fenitic pyroxenes: 1) when pyroxene is not present in the protolith before fenitization as in shale/slates and phyllites at Loe Shilman, then the newly formed pyroxene may not show regular variation in the chemistry and optical properties from the less to highly fenitized rocks. [7]This is interpreted as due to the newly formed nuclei in equilibrium with the carbonatitic fenitizing fluids. [8]Such type of pyroxenes are present in the granitic xenolith, in which pyroxenes grow radially and are formed at the expanse of quartz as a result of Na-fenitizing fluids by the carbonatite. [9]In this case very little but regular change in composition is present because there was originally no pyroxene. [10]2) When pyroxene is present in the protolith, then the overgrowing pyroxene does not require any nucleus for their crystallization. [11]In this case fenitic pyroxene grows around the magmatic pyroxene of the host rock. [12]During the overgrowth the original pyroxene (magmatic or metamorphic) reacts with the fenitizing fluids and a change occurs in the composition and optical properties. [13]The original pyroxene of the protolith may be preserved depending upon the intensity of fenitization.

[14]Such type of Na-pyroxene is present in the Koga fenitized syenites.

[15]The pyroxene compositional trends for different alkaline rocks are shown in Fig. 5 which represent the cooling history of the alkaline rocks. [16]In this figure all the trends show enrichment of the acmitic component. [17]The reverse trend (i.e., from acmite to diopside) is not reported in pyroxenes during fractional crystallization of the alkaline magma.

[18]The reverse trends which are observed in the individual grain of pyroxene from Koga fenitized syenites are interpreted as the result of fenitizing fluids having different Na/K ratios, emanating from the carbonatites. [19]The trend K is the result of fenitizing fluids having low Na/K ratio while trend N is due to emanating fluids having high Na/K ratio.

[20]Similar reverse trends have been reported from the Fen Complex which, according to Kresten & Morogan (1986), are due to the fenitization by the ijolites.

[21]In Koga the fenitization of syenites and granites due to the fluids having high Na/K ratio (trend N) occurs, the possibility of fenitization by ijolite cannot be overruled.

[22]However, the major, trace and REE geochemistry (Jabeen and Mian, in preparation) favours the metasomatism by the carbonatite fluids having high Na/K ratio. [23]The behavior of the second carbonatite (i.e., having high Na/K ratio is almost same as that of the amphibole carbonatite at Silai Patti. [24]In contrast to the fenitic pyroxenes, metasomatic Na-amphibole occurs only in the Na-fenitized syenites.

CONCLUSION

[25]The study of pyriboles from Koga syenites suggests: 1) Fenitization of the rocks by the fluids emanating from carbonatite intrusion.

[26]2) The fenitic pyroxene shows the trend of evolution from acmitic to diopsidic component in contrast to the magmatic trends.

[27]3) The composition of pyroxene further suggests that the Koga rocks have been intruded by at least two carbonatite intrusions having different Na/K ratios.

[28]4) The fenitic Na-amphibole shows trend from magnesioarfvedsonite to richterite which is also opposite to the magmatic subsolidus trend.

[29]5) The amphibole composition shows an increase in MgO ratio with increasing intensity of fenitization and crystallization of fenitic amphibole under strong oxidation state. [30]However, Na-amphibole occurs only in the Na-fenitized syenites.

PAK-08: Large scale vertical aggradation of sandstones in the Kamlial Formation of the Kohat Basin, Pakistan

[1]Molasse sedimentation due to orogenic uplift and southward migrating deformation was active in the Kohat-Potwar foreland basin since late Oligocene (Shah, 1977). [2]Over 6 km thick sand-silt and conglomerate sequence was deposited by palaeoriver systems which changed their pattern with changing positions of the foreland basin with respect to the orogenic belt. [3]Various proportions of sand-silt and conglomeratic facies across the molasse succession was mainly a function of changing river pattern, climatic conditions and subsidence rates in the foreland basin.

[4]The palaeoriver system which deposited the sediments of the Rawalpindi Group was a medium to high sinuosity river system as reflected by the abundance of inchannel lithofacies St (trough cross-bedding) and Sl (low angle palne-bedding).

[5]The very thick sandstones (up to 100 metres) are clearly multistoried, with individual storeys in the order of 4-6 metre thickness, deposited by streams probably 6-8 metres deep. [6]High proportions of intraformational conglomerate are due to reworking of overbank fines by major channels. [7]No exotic conglomerates are found in the Kamlial Formation except a few volcanic and quartzitic pebbles in thick sandstones.

[8]This was probably due to the fact that the site of deposition was towards the distal part of the foreland basin where streams could not transport large clasts in sufficient amount.

[9]Individual bar macroforms and channel-fills are difficult to interpret because of outcrop limitations in the study area. [10]Thick sandstone deposits and vertical stacking of the sandstone-bodies was probably due to low subsidence rates

in the basin coupled with a dominant sand supply from the source area into the foreland-basin.

[11]According to Allen (1978) and Kraus & Middleton (1987) higher interconnectedness of sandstone bodies results in a slowly subsiding basin as a result of low preservation of the overbank fines due to slow burial. [12]Next in-channel flow can erode the overbank fines and deposit intraformational conglomerates.

[13]The river system which deposited molasse sediments of the Rawalpindi Group probably entered the Kohat-Potwar foreland basin through Kohat area and deposited its earlier sediments in the Kohat part of the basin. [14]The molasse sediments are generally diachronous, older in the Kohat area and comparatively younger in the Potwar area (Beck per.comm.).

[15]High sinuosity local streams were active in the flood-plain on a smaller scale depositing small sandstone-bodies (Fig.8). [16]The major river system was flowing to the east (Fig.7).

[17]The flow direction in the Kohat area during the deposition of the Kamlial Formation was similar to that of the Potwar area (Stix, 1982), suggesting that the river systems have been flowing in the same direction throughout the Kohat-Potwar foreland-basin.

PAK-09: Structure and stratigraphy of the Northern Gandghar range, Hazara, Pakistan

[1]Since the Baghdarra fault truncates the northern extension of the Gadwalian fault suggesting that the Gadwalian fault must be older than the Baghdarra fault. [2]Similarly the Sirikot fault is either branching from the Baghdarra fault or is terminated by the Baghdarra fault. [3]If the former is true then they may be of the same age or closely following each other. [4]And if the latter is true then the Sirikot fault must be older than the Baghdarra fault. [5]No age constraints were possible to get on the Darrah fault.

[6]These faults have a few things in common. [7]Firstly, their attitude is more or less the same. [8]Secondly, the basal sequence of their hangingwalls is always the Manki Formation. [9]And thirdly, they do not cross-cut one another.

[10]These features suggest that they are part of an imbricate system, emerging from a common detachment surface that exists at the base of or within the Manki Formation (Fig.4).

[11]The order of development of these faults suggest that the deformation is foreland-directed, and the entire Gandghar Range is being carried in a piggy- back style by the Panjal fault. [12]The piggy-back style of thrusting in the range is also supported by the geometrical elements (dip angles) of the rocks.

[13]The dip angle of the hangingwall rocks of each individual thrust are steeper than those of their respective footwall strata, which is consistent with the geometry of a piggy-back thrusting style.

[14]The rocks of the northern Pakistan are grouped into the "internal" and "external" zones (Coward et al., 1988) on the basis of their grade of metamorphism. [15]The internal zone is characterized by having the high grade metamorphic rocks with their southern limit at the Panjal fault (Fig.1). [16]Westward the Panjal fault is represented by the Khairabad fault (Yeats and Hussain, 1987). [17]The external zone is characterized by having unmetamorphosed sediments with their northern limit at the Nathia Gali fault. [18]The Nathia Gali fault is laterally continuous and is equivalent to the Cherat fault (Fig.1), because both of them are the southern most thrusts which bring the Precambrian basement rocks to the surface.

[19]The rocks between the Khairabad-Panjal fault and Nathia Gali-Cherat fault are either very low in metamorphic grade (green schist facies) or are unmetamorphosed sediments.

[20]It is, therefore, suggested that the internal and external zones be separated by a "transitional zone" which is characterized by having the least metamorphosed Precambrian basement rocks, overlain by virtually unmetamorphosed sediments.

[21]The Gandghar Range can be divided into two blocks: the western and the eastern Gandghar Range, and the two are juxtaposed along the Baghdarra fault. [22]The western Gandghar Range is in itself composed of three sub- structural blocks separated by the Sirikot and Darrah faults. [23]The three blocks located north of the Baghdarra fault i.e., the western Gandghar Range, have same stratigraphy. [24]The eastern Gandghar Range is having a complete succession of Precambrian to Cambrian rocks (Hylland et al., 1988) including the basal Manki Formation followed by the Shahkot Formation, Utch Khattak Formation, Shekhai Formation and the Tanawal Formation (Fig.3). [25]Whereas in the western Gandghar Range the stratigraphy is interrupted by an unconformity between the basal limestone of the Shahkot Formation and the overlying Tanawal Formation. [26]Here not only most of the Shahkot Formation is missing, but the whole of the Utch Khattak and Shekhai Formations are also missing.

[27]The sequence of various lithologies of these blocks suggest that their basin of deposition was gradually getting shallower towards west (Fig.3).

PAK-10: Petrology and the grain size characters of the Pab sandstone of parts of the Loralai and Khuzdar districts of Baluchistan

[1]The Pab Sandstone by nature is moderately to well sorted, symmetrical and mesokurtic. [2]Plot of skewness and sorting (Fig.5) go in favour of the beach conditions although there may be some influence of river in the Murgha Kibzai area.

[3]It has been argued (Mason and Folk, 1958; Friedman, 1967) that beach sediments tend to be negatively skewed and leptokurtic.

[4]The Pab Sandstone, on the contrary, behaves differently which may be due to other influences.

[5]Samples of the Siazgai and Murgha Kibzai areas are rich in limestone/fossil fragments (mostly foramini-fera), otherwise their mineral content and texture show high degree of maturity. [6]On the other hand, sandstone of the Khuzdar area are highly rich in quartz and siliceous fragments and deficient in limestone/fossil fragments.

[7]Therefore, on the basis of both combined grain size and petrographic characters such as high maturity, moderate to well rounded nature of quartz grains, high values of sorting coefficient and presence of calcareous fossil fragments, it may be suggested that the Pab Sandstone was deposited in shallow marine, most probably beach conditions, although river influence may also be noticed, as suggested by some of the grain size analyses.

CONCLUSIONS

[8]Following conclusions may be drawn from the foregoing account of petrographic and grain size analyses:

[9]1) The Pab Sandstone (Late Cretaceous) is classified as quartz arenite, sublithic arenite and lithic arenite and derived from an acid igneous and metamorphic terrain.

[10]2) On the basis of petrographic and grain size characters it may be suggested that the Pab Sandstone has been deposited in shallow marine (most probably beach) conditions.

PAK-11: Lithofacies associations and paleocurrent patterns in the Nagri Formation of the Siwalik group in Kach-Zarghun area of Northeast Baluchistan

[1]Environmental interpretations of these lithofacies associations, based on Miall's (1978) work (Fig.2 & 3, Table 1) have been made. [2]It may be concluded that Sh and Sl are the product of plannar bed flows and antidunes respectively and caused by very high swift floods (McKee et al., 1967).

[3]However, lithofacies St are the product of dunes formed in channels during normal flow conditions whereby their set thicknesses depending on the depth of channels.

[4]Columnar profiles of the Shin Ghundai section (Fig.2) suggest a crudely fining-upwards trend. [5]Plannar crossbedded sandstones (Sp), attributed to the linguoid transverse bars, are present in the upper parts of the sequences.

[6]Road sections near Kach Levy Post (Fig.3) show slumping and frequent occurences of load casts and associated flame structures suggesting unstable depositional conditions perhaps due to higher gradient.

[7]The high proportion of Sh, Sl, and St lithofacies types resemble with the Bijou Creek model of Miall (1978) and the sand dominant braided channel system of Rust (1978) which are the product of high energy flow conditions dominated by flash floods possibly of ephemeral nature.

[8]The occurrence of lithofacies types Sh, Sl, and Se (including Sm) are coupled with very coarse, pebbly and poorly sorted nature of the snadstones which suggest simultaneous deposition of both pebbles and sand perhaps with minor current fluctuations. [9]In this case the larger clasts are rarely larger than medium pebble size (15 mm). [10]Lithofacies Sl is caused by lower-relief scours (Rust, 1978) and Sh analogus to horizontally laminated strata formed on longitudnal bars in proximal gravel systems. [11]Se with mud interclasts, up to several cm across, is also an indication of high competency of the system.

[12]Combination of Sh, Sl and Se (alongwith Sm) assemblages with that of St (Fig.2 & 3) reflect fluctuations in flow conditions and indicate that flow system was less ephemeral and resembles with the Bijou Creek and Malbai type of assemblages.

[13]During flood conditions the size of the dunes responsible for the formation of trough-crossbedding depends on the depth of the channel and thicker (up to 1 m) sets are formed (Cant, 1978), therefore, large troughs (0.6 m deep and 3 m wide) in coarse and pebbly sandstones are characteristic of the sinuous-crested dunes in large deep channels. [14]Plannar crossbeds, on the other hand, are deposited by transverse linguoid bars with slip faces forming their downstream margins (Smith, 1970, 1971; Collinson, 1970).

CONCLUSIONS

[15]1. Eight distinct lithofacies associations namely the Sh (plus Sl), St, Sm, Se, Sp, SSm, SSl, Fl (in descending order) are characteristic of the Nagri Formation, Sh (plus Sl) and St being the most common lithofacies types.

[16]2. Such a combination of lithofacies associations suggests frequent surges of high energy floods with antidunes, scour-fills and plannar bed flows with intermittent periods of normal flows causing dunes and ripples.

[17]3. Paleocurrent patterns suggest a common landmass to the north of Zarghun, east of Gogai and south of Spera Ragha, however, the northern flank of Spera Ragha and Gogai Synclines have derived its detritus from a land mass to the north of Rud Malazai, Malkhezun and Umai.

PAK-12: Stratigraphic control for the age of Peshawar-Plain magmatism, Northern Pakistan

[1]Whereas the external zone of the Himalayan thrust fold belt is completely devoid of magmatic rocks, they are not uncommon in the internal zone. [2]Leaving apart the basement gneisses, such as those exposed in the Nanga Parbat and Besham syntaxes (Coward et al., 1988; Treloar et al., 1989; Baig, 1990), there are at least two major phases of granite magmatism since Cambrian (Le Fort et al., 1980; Jan et al., 1981; Shams, 1983). [3]The first phase is characterised by peraluminous, porphyritic, two-mica augen gneisses. [4]These include Swat and Mansehra granites which are of Cambrian age (Le Fort et al., 1980; Baig, 1990). [5]We tend to include the Chinglai gneisses exposed on the southern border of the Ambela Granitic Complex in this group on the basis of its megacrystic composition, mineralogy characterised by two micas, and peraluminous geochemistry. [6]This implies that the Chinglai gneisses are genetically unrelated with the Ambela Granitic Complex as believed by Siddiqui et al., (1968), and Rafiq (1987). [7]The second phase is distinctly alkaline to peralkaline in chemistry and resembles closely with postorogenic A-type granites (Whalen et al., 1987). [8]These granites are typically distributed in a semicircle around the western, northern and northeastern fringes of the Peshawar plain. [9]They are spatially associated with a suite of undersaturated to mildly oversaturated alkaline to peralkaline magmatism which gives rise to a diverse assemblage of rocks ranging from carbonatites, through ijolites, feldspathoidal syenites to syenites and quartz syenites. [10]Together with the A-type granites, they have been considered to define an alkaline province in the area occupied by Peshawar plain and its surroundings. [11]Then there is the basic magmatism which occurs in the form of an extensive suite of basic dykes and sills. [12]This may be less voluminous than the A-type granites but, unlike the latter, is much more widespread in its distribution from Attock- Cherat range in the south to the Upper Kaghan and Kashmir valleys in the north.

[13]All these igneous rocks are subject of detailed petrological studies for the last several decades.

[14]However, little was known, until recently, about the stratigraphy of the host rocks, except for those inter-stratified with the Panjal basic volcanics which yielded Permian fossils (Bhat et al., 1981). [15]This led to a reliance solely on the radiometric data for the age of the magmatism in the Peshawar plain alkaline province, which were often misinterpreted. [16]For instance, Kempe (1973) reported K/Ar ages of 41, 50 and 100 Ma determined on reibeckite, biotite and nepheline minerals separated from the Warsak granites and Koga syenites, and arbitrarily selected 50 Ma as the age of emplacement of the alkaline province magmatism. [17]Maluski & Matte (1984) presented Ar/Ar data on amphibole and biotite from the Warsak granites yielding ages of 43.5, 40, and 42 Ma which they interpreted to be tectonometamorphic, but their age of emplacement for the Malakand granite (23 Ma) turned out to be much less than that determined by Zeitler (1988) on zircon (Carboniferous). [18]Le Bas et al., (1987) presented Rb/Sr whole-rock isochron data for the Ambela granite and the Koga syenite yielding ages of 315 and 297 Ma, but considered the Sillai Pattai carbonatite to be emplaced at 31 Ma based on the basis of a K/Ar age on biotite, which is highly questionable in the light of existence of a tectonometamorphic event of this age in the same area (Treloar et al., 1989).

[19]A detailed reappraisal of stratigraphy in the recent years in the parts of Peshawar plain and lower Swat valley has resulted in opening new avenues for dating the Peshawar Plain magmatism with a much greater reliability than before (S.R. Khan, in Prep.; Hussain et al., 1990; Pogue et al., 1990).

[20]The volcanic nature of the basalts in the upper parts of the Jafar Kandao Formation confirms their Late Carboniferous-Early Permian age, which coincides closely with the age of the Panjal volcanics from northern Pakistan. [21]Interestingly, whereas the strata older than this age are almost always cross cut by basic dykes, there is a sharp lack of basic dykes and sills in the younger (post Permian) strata (Pogue, personal communication).

[22]We assign all the plutonic and hypabyssal rocks in the Peshawar plain to this event of basic magmatism in Carboniferous-Permian

[23]It has to be noted that a suite of dykes and sills in the Kaghan area has been considered by Papritz & Ray (1989) to be intrusive equivalents of the Permian Panjal volcanics. [24]This would imply a widespread basic magmatic activity at the northern margin of the Indian plate in Late Carboniferous-Permian time.

[25]There is a strong indication that the acid volcanism was erupted more or less simultaneously with the basic volcanics, but intercalations at several horizons in the Jafar Kandao Formation, both below and within the greenschist unit, suggest a wider span of the magmatic activity than that of the basic magmatism. [26]Unlike the case of basic magmatism, there is an indication that the plutonic equivalents of the acid volcanics may be of the same age or younger. [27]For instance, certain phases of the Ambela granite complex not only cross cut the Jafar Kandao Formation, but some intrude the Triassic Baroch Formation. [28]A lack of deformation in the Ambela and Warsak granites compared to the tectonised acid volcanics of the Jafar Kandao Formation favors a younger age of some of the phases of the A-type granites in the Peshawar plain. [29]It has to be noted that a similar relationship exists in the Warsak Igneous Complex where sheared microporhyries are cut across by relatively undeformed peralkaline granites.

[30]We suggest that there was a Carboniferous to Permian acidic magmatic activity (the magma was peraluminous but had A- type geochemical character), which was both erupted as lava flows and tuffs and emplaced as plutons {e.g., sheared garnetiferous microporphyries in Warsak (Tazeem Tahirkheli et al., this volume) and Shewa-Shahbazgarhi (Ahmed et al., this volume), early phase peraluminous-metaluminous granites in the Ambela complex (Rafiq & Jan, 1989)}. [31]This was followed by a phase of peralkaline granites both in Ambela and Warsak, probably in Early Triassic.

[32]There have been suggestions that the alkaline and peralkaline magmatism in the Peshawar plain is related with Permian-Triassic rifting of the Gondwana (Jan & Karim, 1990). [33]Despite a contrasting composition, a more or less similar tectonic setting of origin is suggested by the basic magmatic rocks (Tahirkheli, 1990).

[34]This is, however, not understood that why the A-type granites and peralkaline saturated to undersaturated rocks are restricted only to the Peshawar plain, whereas basic magmatic rocks are widespread throughout the Indian plate north of the Panjal fault.

PAK-13: Myrmekite in the Ambela Granitic complex, N. Pakistan: a product of deformation and replacement in the feldspar

[1]Models explaining the formation of myrmekite mostly advocate readjustments in the relative concentrations of three elements Na, Ca, and K in K-feldspar grains or in some parts of them. [2]For example, Becke (1908) suggested that myrmekites are essentially a product of replacement reactions whereby Na and Ca are introduced and K removed along grain boundaries, resulting in the development of a sodic plagioclase and release of silica as vermicular quartz. [3]Phillips (1980) noted that introduction of water to the system may result in the dissolution of alkali feldspar in myrmekites together with a development of muscovite. [4]Schwantke (1909) accepted the readjustment in the relative proportions of Na, Ca and K in parts of the alkali feldspar grains for the origin of myrmekites, but favoured the mechanism of solid-state diffusion rather than metasomatic replacement. [5]Recently, Simpson (1983,1985) has described myrmekites from high-grade mylonites from the eastern Peninsular Ranges granitoids. [6]These myrmekites are essentially strain-related and were explained to have formed in response to an enhanced solid-state diffusion of Na, under the influence of non-hydrostatic stresses (cf. White, 1975). [7]This model is supported by the position of myrmekites typically at those margins of the K-feldspar porphyroclast which face the maximum shortening direction.

[8]As concluded by Phillips (1980), there is every possibility that myrmekites in nature form due to an interaction of metasomatic replacement and solid-state diffusion-exsolution. [9]It is the petrography which would decide about the dominance of the mechanism responsible for myrmekites in a particular set of rocks.

[10]The myrmekites in the AG°C are characterised by textures which suggest a role of deformation, solid-state diffusion, and reaction replacement. [11]As stated in the previous section, the myrmekite in the AG°C is typically found in the K-feldspar porphyroclasts which are strained, and within them it is always located at the margins which face the maximum shortening direction. [12]The composition of the myrmekite is more albitic than the discrete plagioclase present in the rock, suggesting that they developed locally and subsequent to primary crystallisation. [13]The existence of planner to gently curved boundaries of the myrmekites against the host K-feldspar porphyroclasts lends further support for the strain-related origin of the myrmekites in the AG°C (cf. Simpson, 1985).

[14]There are, however, some differences in the microstructures of the K-feldspar porphyroclasts in the AG°C relative to those of the high-grade myrmekite-bearing mylonites reported by Simpson (1985).

[15]In the latter, the deformation is essentially ductile and there is no evidence of the existence of a fluid phase during deformation as shown by the absence of secondary hydrous minerals like muscovite and sericite. [16]In the case of the AGC, the porphyroclasts display tension gashes and fractures oriented at right angles to the S-foliation planes (Fig. 1C,D,F).

[17]This suggests that the deformation is generally brittle, although limited recrystallisation has taken place in their tails (Fig. 1B). [18]Additionally, there is a close textural relationship between the trails of muscovite and the myrmekites; the latter being commonly rooted in the muscovite trails.

[19]The presence of a fluid phase accompanying deformation has previously been suggested to be responsible for the development of fibrous sillimanite in the AG°C shear zones (Rafiq and Jan, 1987). [20]The loss of K relative to Na and Ca at the K-feldspar porphyroclast margins may partially be associated with the activity of fluids which crystallised muscovite in the adjacent shear planes. [21]The common occurrence of the myrmekites in a bulbous shape with invasive appearance, and the presence of quartz vermicules extending up to the myrmekite-feldspar interface is considered by Phillips (980) and Simpson (1985) to be an evidence for the role of metasomatic replacement.

[22]Thus, although there is little doubt that the myrmekite in the AG°C is formed under a direct role of deformation, the mechanism involved was an interplay of both solid-state diffusion and exsolution and reaction replacement in the presence of fluids.

CONCLUSIONS

[23]The characteristic position of the myrmekites at the margins of the K- feldspar porphyroclasts facing shortening direction indicates some relationship between the formation of myrmekite and deformation. [24]The presence of muscovite along foliation planes, and their close association with the myrmekites suggest an open system, in which fluids facilitated free ionic movement in the replacement reaction. [25]Shear strain was localised along biotite and muscovite-bearing foliation planes anastomosing around K-feldspar grains, which polygonised (or recrystallised) quartz, and strained and partly recrystallised K-feldspar. [26]Solid-state diffusion of Na and Ca to the sites of high strain at the porphyroclast margins might have been partially responsible for the origin of myrmekites. [27]There is, however, a stronger evidence for the role of reaction-replacement in their genesis. [28]Brittle-ductile deformation together with an activity of circulating fluid phases caused dissolution of K-feldspar porphyroclasts in their relatively strained parts depleting them in K relative to Ca and Na, which resulted in

the formation of myrmekites in close association with muscovite.

PAK-14: Petrography and geochemistry of the inclusions from the Ambela Granitic complex, N. Pakistan

[1]The megascale characteristics of the outcrops show that the inclusions were incorporated into the host granitic and syenitic magma as blocks, fragments and partially fused material. [2]This character is clearly reflected in their rounded shape, lobate to serrated boundaries and, at places, wispy protrusions into granites. [3]Inclusions in the syenitic rocks in the northern part of the complex may show extreme elongation (plastic flow) and at least some partial melting. [4]Similar features have been widely recognized in the plutonic environments (e.g., Wiebe, 1974; Vernon, 1983,1984; Reid et at., 1983; Moyes, 1986).

[5]Major element geochemistry of these inclusions is inconclusive with regards to their origin. [6]There are distinct differences between the composition of inclusions and their host granites and syenites in terms of elements such as SiO2, Al2O3, MgO and CaO (Table 1). [7]These differences, however, are not reflected in trace-element composition. [8]In particular, the incompatible trace elements such as Rb, Ba, K, Nb, LREE, Zr, P, Ti and Y in the inclusions generally correspond with the host granites and syenites, in terms of concentration.

[9]Similar concentration levels of these incompatible trace elements are also found in acid volcanic rocks exposed at the marginal contacts in the northwest, west, and south of AGC.

[10]These are thought to be related to AG°C and are an extension of other volcanic and subvolcanic rocks of the Peshawar plain including those of the Shewa-Shabazgarhi (Rafiq, 1987, and in prep.).

[11]In Figure 1, mantle-normalised trace elements pattern of the inclusions are compared with those of the Ambela granites, syenites and volcanic rocks. [12]As far as the general concentration is concerned, the inclusions are not substantially different from all the three lithologies represented for comparison. [13]Both the Ambela granites and syenites are characterised by a general negative Nb anomaly which is particularly pronounced in one of the later. [14]Also the Rb-Ce segment of the pattern in granites and syenites is generally significantly spiked. [15]In comparison, the trace element pattern of the inclusions are characterised by a flat Rb-Ce segment and a positive Nb anomaly.

[16]These features of the incompatible trace elements of the inclusions are closely comparable with the patterns of the volcanic rocks, suggesting that these inclusions were derived from the acidic volcanic phases of the region which partly made country rocks to the AGC.

PAK-15: Stratigraphy of the Dungan group in Kach-Ziarat area, N.E. Balochistan

[1]The strata overlying the Cretaceous Parh Formation and underlying the Eocene Ghazij Formation have been described as Dungan Limestone (Oldham, 1890). [2]Williams (1959) and Hunting Survey Corporation (1960) have attempted to subdivide the Dungan Limestone. [3]Their views and the author's suggestions have been summarised in Table 4.

[4]William's (1959) work in northeast Balochistan is based on the study of selected sections between Quetta and the Sulaiman Range. [5]The HS°C (1960) work is based on more extensive regional, but reconnaissance type of photogeological work.

[6]Present studies are based on several sections between Loralai, Quetta and Kalat and it appears that at least in this region it would not be proper to designate the Dungan Group of rocks by many names as proposed by William(1959) and HS°C (1960). [7]Evidently the strata lying between the Parh Formation and the Ghazij Formation essentially comprise two major lithostratigraphic units.

[8]The upper unit is medium- to thick-bedded and massive limestone, commonly with nodular or rubbly character, with interbeds of shale, and a fauna of Palaeocene to Lower Eocene larger foraminifera (cr. Dungan Limestone and Fort Monro Limestone of Williams, 1959), the Sanjawi Limestone, most of the Brewery Limestone and upper part of Moro Formation of HS°C (1960), and the Dungan Limestone of present studies. [9]The lower unit comprises interbedded dark grey mudstone, argillaceous limestones and sandstone (orthoquartzitic) with conglomerate layers, breccia, lateritic shale, laterite or basalt at base (cr. Moghal Kot Formation and Kahan Conglomerate ofWilliams, 1959; lower part of Moro Formation of HSC, 1960); and the Bibai Formation of present studies). [10]The lower unit is essentially characterised by a Maestrichtian foraminifera, largely comprised of Omphalocyclys macropora, orbitoides sp. and Siderolites sp.

[11]It is proposed that the name Bibai Formation be adopted because it is near Kahan that the true nature of the lower unit is revealed and a clear picture of the prevailing environment can be obtained.

[12]The lithology of Moghal Kot Formation (William, 1959) and Moro Formation (HSC, 1960) arevery similar to the Bibai Formation near Kahan, except that the sections north of Kahan (and east of Kach) contain basalt at the base and a vast thickness of boulder conglomerate higher up.

[13]Present studies clearly signify the need for more comprehensive and systematic litho- and bio-stratigraphic studies of closely spaced section for an adequate subdivision of the Dungan Group (formations and members). [14]Until such time it would be appropriate to subdivide these strata into two easily recognisable and mappable units an upper Dungan Limestone, and a lower Bibai Formation.

PAK-16: Clay mineralogy of the quaternary lake deposits of Peshawar Basin, at Jehangira, District Mardan, N.W.F.P., Pakistan

[1]In the non-marine sedimentary basins chlorites are derived from the weathering profiles by the degradation of ferromagnesian minerals, and above all, from the erosion of the greenschists which have abundant chlorite. [2]Chlorites may also be formed diagenetically in the "Anchi-" and "Epizones" (close to low grade metamorphism), by the aggradation of less organized sheet minerals such as celedonite and montmorillonite (Dunoyer de Segonzac, 1970; Deer et al., 1976). [3]The 2M form of illite is found in micas of metamorphic zones or in deep diagenetic zones bordering on metamorphism (Kisch, 1970; Dunoyer de Segonzac, 1968, 1970; Weaver, 1958). [4]Thus the 2M illites in recent continental sediments are usually of detrital origin and are common where the cold and dry climate was not favourable to hydrolysis or where erosion was sufficiently rapid to prevent weathering (Dunoyer de Segonzac, 1970; Kisch, 1966, 1968). [5]As for montmorillonite, it occurs in four special environments: in soil profiles, in basic chemical sedimentation, in bentonites (altered volcanic ash) and in hydrothermal veins. [6]In well drained soils illite and chlorite are degraded to

montmorillonite which forms and intermediate stage before their total hydrolysis. [7]As for chemical sedimentation of montmorillonite, the environment has to be of alkaline (high pH), and "non-aggressive" type (Grim, 1953; Millot, 1964; Dunoyer de Segonzac, 1970).

[8]The lake deposits of Jehangira and the claystone of the Siwaliks Group do not show any signs of even very low grade metamorphism.

[9]Thus, in these deposits the presence of regular well-formed chlorite and the 2M illite, co- existing with the expanding clay (i.e., montmorillonite), cannot be attributed to diagenetic neo-formation. [10]Hence, it is inferred that these illites and chlorites are of detrital origin, derived mostly from the abundant mafic, ultramafic metamorphites of the Kohistan arc sequence, the Indus Suture melange group of MMT (green-schists, blueschists, talc-chlorite-dolomite and quartz-mica- chlorite schists) and the schistose rocks of the Indo-Pakistan sequence south of MMT (Kazmi et al., 1984; Jan, 1979).

[11]Since chlorites and illites are the retromorphic products of ferromagnesian minerals, they would form a major portion of the soils at the foothills of the Central and Lesser Himalayas. [12]Further degradation of these illites and chlorite produces montmorillonite which is brought down with the drainage and subsequently deposited in the sedimentary basins further south. [13]This is interred to be the dominant mode of formation of montmorillonite in both, the lake as well as the studied Siwalik deposits. [14]Nevertheless, the in situ formation of some of the montmorillonite in the Jehangira lake deposits cannot be ruled out. [15]In such a case, alkaline (high pH) and non-aggressive conditions would be depicted. [16]Presence of some carbonate and the absence of kaolinite in these lake deposits also supports this inference (Grim, 1953; Dunoyer de Segonzac, 1970).

[17]Our present study reveals that there is a similarity between the clay mineral assemblages of the Jehangira lake deposits and the Lower Siwalik Clay of the Chinji Formation. [18]Thus it is inferred that the source of the two deposits was the same, i.e., the mafic, ultramafic metamorphites of the Kohistan sequence and the MMT melange zone, and the schist of the Indo-Pakistan plate sequence south of MMT.

[19]A detailed study of the clay minerals of the various outcrops of Quaternary lacustrine deposits of Peshawar valley is in progress.

CONCLUSIONS

[20]The Jehangira lake deposits were studied for the purpose of identification of clay minerals using X-ray Diffraction. [21]The studies reveal the presence of illite, chlorite and montmorillonite. [22]Samples from the bright red claystone of the Chinji Formation of the Siwalik Group were also analyzed for comparison sake.

[23]Illite and chlorite in both, the Jehangira lake deposits and the claystone of the Chinji Formation are of detrital origin as revealed by their regular and well formed structures. [24]The parent material for these detrital clay minerals, are the abundant mafic, ultramafic metamorphites in northern Pakistan. [25]The similarity of clay mineral assemblages between the Jehangira lake deposits and the Chinji claystone suggests a common provenance.

[26]Montmorillonite in the clays were derived by the degradation of illites and chlorites in the soils near the foothills and in the valleys of the Central and Lesser Himalayas. [27]In the lake deposits of jehangira some of the montmorillonite could be of authigenic origin indicating alkaline and quiescent environment.

PAK-17: Island arc signatures from the Waziristan igneous complex, N.W.F.P., Pakistan

[1]The mineral compositions of the ultramafic and mafic rocks of the Waziristan igneous complex indicate that they are not in complete semblance with the rocks of oceanic crust or the typical ophiolite suites. [2]Rather, more than to any other affinity, they point towards an island arc origin. [3]In the ultramafic cumulates, the olivine consistently shows a high Fe content of 89 to 91. [4]Similarly, the dino- and orthopyroxenes of these cumulates are also highly magnesian (100 Mg/(Mg + Fe) = 89-95) (Fig 3). [5]The absence or near absence of plagioclase and the presence of highly magnesian olivine and pyroxene in these ultramafic cumulates indicates that they were formed by high pressure (10 kbar) crystal fractionation (Elthon et al., 1982).

[6]In case of primary magmas proposed for oceanic basalts, it has been shown by Elthon et al., (1982) that for low to moderate pressures (kbar) olivine is the liquidus phase and is followed by plagioclase and clinopyroxene, whereas under higher pressures (10 kbar), clinopyroxene crystallizes before plagioclase.

[7]The high Mg# of the analyzed pyroxenes and olivines (Table 1) is in agreement with the values predicted by Elthon et al., (1982) for such high pressure cumulus phases.

[8]Normally in the oceanic crust, orthopyroxene is not a dominant cumulus phase, rather it occurs as a late intercumulus mineral (cf. Burns, 1985). [9]In the studied peridotite from the Waziristan igneous complex, orthopyroxene is an obvious cumulus phase, indicating the same paragenesis (i.e., high degree of Si saturation in the melt than MORB magmas, or crystallization at moderate pressures), as the Border Ranges ultramafic complex, which represents the root of an island arc (Burns, 1985). [10]These features show a prominent contrast with the rocks of the oceanic crust which generally crystallize in a low pressure environment (2.5 kbar) (Flower et al., 1977; Sleep, 1975; Dewey and Kidd, 1977). [11]Though some high pressure crystal fractionation does occur at greater depths (30km) in the mantle beneath the oceanic ridges, but these have been reported as anomalous features in the oceanic crust (e.g., Elthon et al., 1982).

[12]Such high pressure environments would be more likely at the base of island arcs (e.g., Burns, 1985).

[13]The spinels can provide useful clues for discriminating the tectonic settings. [14]According to Dick and Bullen (1984), spinels with Cr# [Cr/(Cr + Al) 1 0.6 are typical of oceanic crust. [15]Whereas spinels with Cr# 0.6 are found in volcanic arcs, stratiform complexes, zoned Alaskan complexes and oceanic plateau basalts.

[16]The spinels from the peridotite of the Waziristan igneous complex contain Cr# greater than 0.6 and thus show a definite contrast with abyssal peridotites. [17]Although these spinels plot in the "alpine peridotite" field on the Cr-Al-$Fe3+$ + Ti diagram (Jan et al., 1985), it is interesting to note that the spinels from the Border Ranges ultramafic complex (Burns, 1985), also plot in the same field.

[18]Thus it is suggested that these rocks cannot be unequivocally called upper mantle tectonites on the basis of this diagram. [19]Other characteristics of these peridotites from Waziristan, such as their cumulate texture and absence of strong tectonite fabric also support their island arc origin, along with the additional evidences from the related rocks as discussed below.

[20]A prominent feature of the gabbros from the Waziristan igneous complex is that they invariably contain unzoned Ca-rich plagioclase (An), which is comparable with the Ca-rich plagioclase commonly associated with island arc magmatism.

[21]An (90-100) is a prominent and essential constituent of basic volcanic rocks of calc-alkaline suits of present-day circum-oceanic island arc where it occurs as phenocrysts in basalt flows (Byers, 1955; Lewis, 1973). [22]It also occurs in plutonic ejecta from these volcanoes, as in the plutonic blocks from Soufriere volcano, West Indies (Lewis, 1973) and islands in the Lesser Antilles (Arculus and Wills, 1980). [23]Besides, such a highly Ca-rich plagioclase is also found in basic plutonic rocks of calc-alkaline suites like the Batholith of Southern California (Miller, 1937), Border Ranges mafic-ultramafic complex (Burns, 1985) and the Chilas complex (Jan et al., 1984; Khan et al., in press).

[24]In the studied gabbros of the Waziristan igneous complex, the clinopyroxene is commonly enclosed poikilitically in plagioclase. [25]This feature also suggest crystallization of

clinopyroxene prior to plagioclase, indicating high pressure (10 kbar) crystallization. [26]The pyroxenes of the studied gabbros generally shows Alvi/Aliv ratios, ranging from 1.29 to 0.28 (with a few values 0.2), which indicate higher pressures of crystallization uncommon of shallow crystal igneous rocks (Aoki and Kushiro, 1968).

[27]Such Alvi/Aliv ratios of these pyroxenes and their crystallization prior to plagioclase further contradict oceanic crust affinity and favours an island arc origin for Waziristan igneous complex. [28]This interpretation is also supported by the An mole% of plagioclase vs. Mg# [100Mg/(Mg+Fe)] of the coexisting clinopyroxenes plot (Fig.4; cf. Burns, 1985).

[29]The chemical composition of primary clino-pyroxenes reflects the chemistry of host rocks (Kushiro, 1960; Le Bas, 1962; Verhoogen, 1962; Deer et al., 1978; Hamidullah and Bowes, in press. [30]In view of this, the clinopyroxenes have been previously used for discrimination of different palaeotectonic settings (Nichet and Pearce, 1977; Leterrier et al., 1982; Capedri and Venturelli, 1979).

[31]The clinopyroxenes from the gabbro, diabase and volcanics of the Waziristan igneous complex were similarly employed for the purpose of working out the magmatic affinity of the complex.

[32]The clinopyroxenes from the studied area differ from the alkaline rocks by virtue of their lower Ti and Al contents (Tables 2 and 3). [33]Their non-alkaline nature is further indicated by Figures 5 and 6. [34]The trend shown by these pyroxenes on the Alz vs. TiO2 diagram (Fig 5) of Le Bas (1962) and Kushiro (1960), probably indicates increasing PH2a with crystallization (see Hamidullah, 1983; Hamidullah and Bowes, in press).

[35]The low Ti and Cr values of these pyroxenes evince their similarity with rocks from supra-Benioff zone (including island arc tholeiites and calc-alkaline basalts), and contradict their oceanic crust affinity (Fig. 7). [36]Figure 8 shows that the pyroxenes from the volcanics of the Waziristan complex are of calc- alkaline type, whereas those from the diabase and the gabbros are of island arc tholeiitic nature.

[37]The TiO-MnO-Na20 discrimination diagram of Nisbet and Pearce (1977) also supports the volcanic-arc affinity of these rocks (Fig 9).

[38]The clinopyroxenes from the volcanics plot in the mixed field of this diagram, whereas most of clinopyroxenes from the diabase and the gabbros dominantly plot in field for volcanic-arc basalts, with some occupying the common field for volcanic-arc basalts and within-plate alkalic basalts.

[39]As the alkalic nature of these pyroxenes has been ruled out above, the volcanic arc- affinity remains the only alternate origin suggested by this diagram too. [40]The copper mineralization associated with the rocks of the complex is probably the result of this island arc volcanism also (cf. Mitchell and Bell. 1973).

[41]In view of these mineralogical characters of the rocks from Waziristan igneous complex, it is suggested that these rocks represent a tectonically dismembered and fragmented island arc suite. [42]The tectono-stratigraphical position of the complex indicates its temporal relation with other island arc- related rocks along the suture zone between Indo-Pakistan plate and the northern continental blocks.

CONCLUSIONS

[43]Present study of the Waziristan igneous complex provides evidences for the supra-Benioff zone parentage of this complex. [44]The ultramafic and mafic plutonic rocks of the complex indicate crystallization under high pressures (10 kbar). [45]Such high pressures are more likely at the base of an island arc than oceanic crust. [46]The mineral chemistry of the plutonics as well as the volcanics of the complex also contradicts their relation to oceanic crust and shows a greater similarity with island-arc related rocks. [47]The Waziristan igneous complex is thus related to the volcanic-arc activity which took place as a consequence of the northward drift of the Indo-Pakistan plate. [48]The complex was emplaced tectonically in its present position in Palaeocene to early Eocene, due to the final collision of the Indo-Pakistan plate with the northern continental masses.

[49]Further investigations, including detailed sampling for trace elements and REE studies, are needed to elaborate the extent and geochemistry of the complex.

PAK-18: Petrology of Kakul phosphorites, District Abbottabad, N.W.F.P., Pakistan

[1]The petrological studies indicate that the Kakul phosphorite is of two types – pelletal phosphorite and microsphorite. [2]Their close association suggests little difference in sedimentary environments. [3]The pelletal phosphorite is indicative of marginally agitated basinal waters, the microsphorite layers show evidences of authigenic precipitation in quite shallow marine environment.

[4]Two phosphatic horizons are noticed in Kakul, the lower one is hosted in dolomitic limestone. [5]There are underformed pellets of uniform size, which are oval in shape and light brown in colour (Fig. 3). [6]While the upper phosphate horizon is restricted to cherty dolomite. [7]The pellets show variation in their shape and size. [8]Mostly the pellets are elliptical in nature and are aligned (Fig. 4). [9]The recrystallized and secondary minerals are present in large amounts.

[10]These features indicate regional deformation. [11]The diagenetic effects suggest that primary microsphorite has been replaced by secondary calcite. [12]Some of the primary calcite has also been phosphatized. [13]The process of calcitization of primary phosphate has dominated over the processes of phosphatization of carbonates.

[14]The associated silica occurring as cryptocrystalline quartz could have formed as diagenetic inclusions or even as primary silica precipitate.

PAK-19: Sedimentology of the Ghazij Formation, Kach area, Baluchistan

[1]According to the delta model the sequences of a prograding delta show coarsening-upwards cycles. [2]Other characters include occurrence of occasional turbidites and thin shelled pelecypods in shaley units, bioturbation and associated deposits of swamps and meandering rivers.

[3]In sequences of the Ghazij Formation of Kach area the coarsening-upward cycles are not very clear.

[4]These cycles may undoubtfully have been disturbed by folding and faulting. [5]Figure 6, showing the lithofacies associations suggests that the sequence is divisible into following three zones:

1. A lower, shale dominant zone with occasional turbidites. 2. An upper zone with higher proportion of sandstone and conglomerate, although shales dominate. 3. Higher shale dominant zone.

[6]It is proposed that the lowermost shale dominant zone represents the prodelta (marine) clay deposit and the zone with high proportion of sandstones and conglomerates represents deposits of delta slope and platform. [7]The uppermost shale dominant part again shows prodelta deposits that suggest transgression of the sea. [8]Apart from this broad picture, characters like the occurrence of coal seams, cross-bedded and rippled coarse sandstones and conglomerates, and mudcracks represent characteristics of associated swamps and meandering river deposits. [9]It may be said that although lithofacies associations of the Ghazij Formation do not exactly correspond to those of the ideal coarsening-upwards cycles

of the deltaic deposits, other associated characters are comparable with them.

CONCLUSIONS

[10]a) Sedimentary structures and lithofacies associations of the Ghazij Formation support a deltaic origin of the succession. [11]b) The uppermost shale-dominant part of the succession indicate that deposits of the prograding delta were succeeded by marine clays, suggesting a marine transgression. [12]c) High variance of the current directions support its deltaic origin, although disturbance may also have been caused by folding and faulting. [13]Palaeocurrent directions show a general westward flow of the delta.

PAK-20: Preliminary petrochemical study of the Chilas complex, Kohistan island arc, Northern Pakistan

[1]Previous workers (Asif et al., 1985; Jan et al., 1984) have suggested three alternative evolutionary mechanisms for the development of the Chilas complex:

a. Existence of a zoned magma chamber with a main upper portion of gabbronoritic liquid and a base of picritic composition. The crystallization of the upper part was followed by the intrusion of the picritic magma.

b. Picritic magma intruded from deeper levels at the base of a crystallizing magma chamber of gabbronoritic composition.

c. All the rocks types of the Chilas complex have crystallized from one and the same magma and the ultramafic rocks represent remobilised early cumulates.

[2]The continuous variation and general correspondence in major element chemistry of the various basic and intermediate types, reflected in oxide vs D.I. and CMAS plots, indicate an igneous parentage, the control of crystallization differentiation and a genetic relationship among the various rock types of the Chilas complex. [3]The same features are also indicated by the general parallelism of correspondence of the chemical trend of the cumulative rocks (ultramafic rocks and anorthosites) with those of the gabbronorites and amphibolites on many of the variation diagrams and thus favour the third possibility mentioned above (cf. Fig. 5a, c, d, j). [4]Bends and gaps in the variation trends are considered to be related to the appearance and disappearance of various phases on the liquidus, however, the gaps may simply be due to the lack of representative samples.

[5]The affinity diagrams (Fig. 2-4) show that the various rock types of the Chilas complex have crystallized from a basic magma of calcalkaline character. [6]The extensive volume of the gabbronorites may, however, be related to crystallization of this magma in more than one magma chambers.

[7]The development of the ultramafic rocks has been considered as a result of dominant olivine fractionation subsequently accompanied and replaced by orthopyroxene fractionation. [8]A genetic relationship between these rocks and gabbronorite has been already mentioned above.

[9]No olivine relics have been, however, noticed in gabbronorites.

[10]Considering crystallization in a Fo-En- SiO2 system (Anderson, 1915), this feature can be related to the accumulation of most of the olivine, resulting in the production of what is now dunite and peridotite at the base(s) of hypothetical magma chamber(s) and to the complete resorption of the remaining olivine crystals in the stability field of orthopyroxene. [11]The complete resorption of olivine will occur only if the original magma composition lies in the stability field of protoenstatite, more or less dose to composition 'N' in a Mg2SiO4-CaAl2Si2Os-SiO2 system (Fig. 8). [12]The calcalkaline characters suggested for the parent liquid of the rocks of the Chilas complex may correspond to such a hypothetical magma composition. [13]Ignoring the crystallization of the minor proportion of spinel in the early stages of fractionation history, such a composition is expected to crystallize olivine but will react to form enstatite from all the existing olivine under equilibrium conditions. [14]With crystallization of orthopyroxene the changing residual liquid composition will follow a path N-P towards the En-An boundary and at P both enstatite and plagioclase will crystallize together (see Sood 1980, p.24).

[15]Such a crystallization model is consistent with that postulated for the gabbronorites on the basis of CMAS plots as with the presence of very minor proportions of normative olivine in a few gabbronorites. [16]These may have disappeared during metamorphism (Jan, 1977a).

[17]As mentioned earlier the occurrence of ultramafic rocks at the present level of erosion and seemingly intrusive into gabbronorites can be attributed to the emplacement of the former types as plastically remobilised bodies into the later type (cf. Jan, 1980, 1983).

[18]Orthopyroxenite and anorthosite occur in layers, generally interbedded with main gabbronorite. [19]Inspite the fact that rocks of the Chilas complex have undergone a considerable polyphase deformation, the layers are considered to be of igneous origin. [20]Extreme type pyroxenite and anorthosite are generally scarce and in contrast to the known layered complexes (i.e., Bushvald and Stillwater), there is no evidence of a specific horizon to indicate the confinement of orthopyroxenite or anorthosite to the base of the complex. [21]These features and the CMAS plots together indicate that orthopyroxenite, anorthosite and gabbronorite probably developed during the alternating episodes of the dominance of ortho-pyroxene or plagioclase or orthopyroxene + plagioclase, respectively, on the liquidus along P-E in the Mg2SiO- CaAl2 Si2O-SiO2 system (Fig. 8). [22]The decrease on the liquidus, in the proportion of plagioclase during the formation of pyroxenite and of orthopyroxene during the formation of anorthosite can be explained on the basis of compositional variations, particularly Al203 content of the liquid.

[23]Breman (1983) studying the behaviour of crystallization in CaO-MgO-Al203- SiO2 system at 1 atm pressure found that basaltic liquids containing Al2O3 15 wt.% did not crystallize plagioclase. [24]Instead clinopyroxene and orthopyroxene were the dominant phases on the liquidus. [25]Anorthite appeared on the liquidus at the expense of diopside when the Al203 content of the liquid reached upto 15 wt.%. [26]At 20 wt% Al20 the enstatite stability field started shrinking and at 25 wt.% Al 03 enstatite was also no more a stable phase.

[27]These evidences, and the presence of the plagioclase fractionation shown by the chemistry of the majority of the rocks from the Chilas complex, indicate that Al203 content of the liquid from which orthopyroxenite, anorthosite and the gabbronoritic members crystallized, was more or less in the range of c.15- 20 wt.%.

[28]This interpretation is consistent with the Al 03 contents of most of the gabbronorite compositions (see Table 1). [29]It also explains the dominance of orthopyroxene over clinopyroxene in the suite. [30]In addition the content of Al203 must have been varying with crystallization, resulting in a variable proportions of orthopyroxene, clino-pyroxene and plagioclase and thus, giving rise to interbedded gabbronorite (pyroxene granulite) pyroxenites and anorthosite.

[31]Majority of the main gabbronorite compositions indicate normative quartz while modal quartz is present in these rocks and its proportion increases in the intermediate members. [32]Inclusions of quartz have been also noticed in other minerals (cf. Jan, 1979). [33]These features suggest that due to the crystallization of orthopyroxene and plagioclase in gabbronorite, orthopyroxenite and anorthosite, the residual liquid successively became richer in SiO2, and quartz appeared on the liquidus at the later stages of the noritic crystallization.

[34]This interpretation is consistent with the crystallization of anorthite and enstatite along the eutectic path P-E and association of tridymite with these phases at cotectic E, in a Mg2SiO-CaAl2Si2O-SiO2 system (Fig. 8). [35]The development of a silica mineral at the final stage of crystallization in noritic magma is also consistent with the consideration of the composition of the original liquid as being closer to 'N' in the Mg2SiO4-CaAl2 Si2O-SiO2 system. [36]Crystallization along path P-E in Figure 8, from an original magma composition more basic than 'N' may terminate before the residual

magma composition reaches E and thus may not crystallize a silica mineral as the final phase on the liquidus (see Sood 1981 p.25-26).

[37]Compositional plots of the altered pyroxenite in the various projections of the CMAS model indicate the dominant control of clinopyroxene fractionation. [38]Modal clinopyroxene has also been noticed in gabbronorite and some other rocks. [39]These features indicate that clinopyroxene has also played some role in the evolution of rocks of the Chilas complex. [40]Considering the crystallization of such clinopyroxene with orthopyroxene and plagioclase, a temperature of about 1200°C and pressure of 10kb are suggested for the development of this assemblage in the Chilas complex. [41]This assumption is based on experimental data in a projection from CMS2 into MgO-CaAl2O-SiO2 plane of the CMAS system (see Basaltic volcanism study project, 1981, p.598, Fig. 3.6.1A), and the supposition that igneous crystallization has followed a path N-P-E in the Mg2SiO-CaAl1Si2O-SiO2 system (Fig. 8). [42]This would in turn show that the presumed magma chamber(s) in which the crystallization occurred, existed at a depth of 35 km.

[43]According to Jan (1977a) the pyroxene granulite facies metamorphism occurred at a depth of about 25 km (pressure of 5.5-7 kb) and the nearby garnet granulites of the Jijal ultramafic complex indicate further recrystallization of the pyroxene granulite at a depth of 40 km.

[44]All these features indicate that either the gabbronorite, anorthosite and ultramafic rocks of the Chilas complex originated in magma chamber(s) at a depth of 25 km and were later on recrystallized under the granulite facies conditions due to subduction, folding or increase in thickness of the overlying volcanic piles or the whole igneous crystallization occurred under the pyroxene granulite facies condition i.e., at a depth of about 25 km (cf. Jan, 1980).

[45]The amphibolite bodies intimately associated with gabbronorite (pyroxene granulite, cf. section 1) have been considered as the retrograde products of the pyroxene granulites, mainly due to the influx of water during obduction (Jan, 1980). [46]The genetic relationship shown by the major element chemistry of the two types supports such a view.

[47]Jan (1977) has put forward several views about the source material for the parent magma of the Chilas complex. [48]With the present limited data available it is difficult to support any view point.

[49]However, the calcalkaline affinities and similarities of the suite to major plutonic rocks of island arcs suggest that its origin was in some way related to subduction of an oceanic lithosphere during the formation of the Kohistan island arc.

[50]This view is further corroborated by the similarity of mineral phases in the Chilas complex and island arcs plutonic rocks (Jan, unpublished data).

CONCLUSIONS

[51]1. The gabbronorites, amphibolites, peridotites, pyroxenites, troctolites and olivine gabbros, and anorthosites of the Chilas complex represent a cognate magmatic suite of rocks produced as a result of crystallization differentiation from a parent magma of calcalkaline characters, originated in arc-related orogenic environments.

[52]2. Olivine was the earliest mineral on the liquidus followed and subsequently replaced by orthopyroxene.

[53]3. Accumulation of olivine to the base(s) of magma chamber(s) was probably responsible for the development of olivine-rich cumulate rocks.

[54]4. Orthopyroxene was accompanied by plagioclase on the liquidus and ortho- pyroxenite, gabbronorite and anorthosite developed as a result of dominance of orthopyroxene, orthopyroxene + plagioclase and plagioclase, respectively, on the liquidus at the various stages of crystallization differentiation. [55]The dominance of these particular phases on the liquidus, at a particular time, was probably controlled by the changing magmatic composition (especially Al2O content) and/or pressure due to crystallization. [56]It is, however, likely that the compositional variations observed were a product of several combined processes including crystallization differentiation, accumulation, crystal sorting and subsequent compaction of the cumulate piles.

[57]5. Plagioclase associated with and/or replaced olivine locally on the liquidus which led to the development of troctolite, olivine gabbro and feldspathic peridotite.

[58]6. Quartz crystallized as one of the final products of crystallization differentiation from the residual liquid.

[59]7. The major part of crystallization probably occurred at a temperature of about 1200°C and at a depth of 25 km.

[60]8. Recrystallization of the rocks under the pyroxene granulite facies environment was probably due to subduction, folding or increase in thickness of the volcanic piles to a depth of 20-25 km.

[61]9. The genetic relationship of the gabbronorites and amphibolites revealed by the chemistry of these rocks confirms that the latter type is the retrogressive metamorphic product of the former.

[62]10. Ultramafic rocks probably represent genetically related early cumulates remobilized into gabbronorites.

PAK-21: Petrology of the Swat amphibolites and the development of a "Lesser Himalayan" Basin

[1]A model for the development of the basin by the rifting of continental crust and the extrusion of flood basalts over a large part of the incipient basin is proposed. [2]Temporal constraint on this event is the 510-520 m.y. age of the gneisses (Rb/Sr whole rock isochron, Le Fort et al., 1983). [3]Also by the early Devonian, reefoid carbonates were flourishing over much of the northern Indian plate (Stauffer, 1968). [4]Thus, during the Silurian, a widespread rifting episode probably occurred over much of the northern margin of the present Indian plate. [5]Lithospheric cooling during extension resulted in subsidence of the rifted margin (Steckler and Watts, 1978; Royden and Keen, 1980). [6]Extensive flood basalts preceded the gradual subsidence of the developing basin (Fig.7). [7]Such a process was probably operative along the length of the present Lesser Himalayas, forming the passive margin that characterizes the northern part of the Indian plate during the Middle Palaeozoic (cf. the reconstructions by Klootwijk, 1979, and Rickard and Belbin, 1980).

[8]The basalts were erupted on a granitic basement with a thin covering of feldspathic sediments (arkoses). [9]Thin calcareous layers were developed in places. [10]Quartzite and micaschist represent contemporaneous fluvial/marine activity, and the upper surface of the lavas probably underwent some erosion before it was submerged. [11]Carbonate development began before the termination of magmatic activity in the basin, and shallow marine conditions probably alternated with continental ones.

[12]Calcareous schists and impure marbles overlying the basalts were probably derived by the breakdown of the reefs flourishing in the basin. [13]Actual reefs may not have developed in the Mingora area, but were present to the south. [14]Minor igneous activity may have continued during the early phase of deposition and some dykes and sills intruded the flows and even the basal layers of the carbonates. [15]The lime sands and muds were mixed with carbonaceous clastic mud that was being deposited further offshore. [16]Thick calcshales were formed in this manner. [17]Continued marine transgression resulted in the deposition of thick black shales overlying the calcareous strata. [18]This was probably due to anoxic bottom conditions on the shelf, such as described by Leggett (1980) for Lower Palaeozoic black shales of the British isles. [19]Thin ferruginous sand layers and small pebbles have been recorded in places in the graphitic schists.

CONCLUSIONS

[20]Geochemical analysis of amphibolites intercalated with magnesian marbles, calcsilicates and schists, indicates an igneous origin for these rocks. [21]Recent field work near Al-

purai has revealed relict intrusive features in garnet amphibolites identical to those of Mingora. [22]The parent rocks were basalts of CFB-affinity erupted in a zone of crustal attenuation similar to basalts from Greenland (Brooks and Nielson, 1982; Kalsbeek and Jepsen, 1984), Brazil (Bellieni et al., 1984; Fodor and Vetter, 1984), Deccan and Africa (Cox, 1980). [23]This indication of rifting is accompanied by evidence of subsequent subsidence, marine transgression and passive margin sedimentation. [24]Subject to uncertainties in the ages of the overlying carbonates, these amphibolites are evidence of Siluro-Devonian magmatism.

[25]Taken together the evidence suggests the development of a Middle Palaeozoic passive margin and the opening of an ocean, possibly the Palaeotethys.

[26]The extent of this basin has been traced from Malakand in the west to Besham in the east. [27]The gneissic basement has a known extent along most of the Lesser Himalayas (Le Fort et al., 1983). [28]Le Fort (1975) has described "a remarkable lithologic control of the gneisses by quartzite, carbonaceous schist levels, and more or less dolomitic limestones that play a marker part along the 1200 km recognized". [29]Further, he adds that the gneisses are often associated with amphibolites, which he tentatively relates to a Silurian- Devonian infilling of the Lesser Himalaya's basin. [30]This account is strongly reminiscent of the Swat region.

PAK-22: Geology and petrology of the Malakand granite, gneiss and metasedimentary complex

[1]The Malakand granite, gneiss and metasedimentary complex represents rocks of highly variable lithology which have presumably passed through a complex pattern of evolutionary processes.

[2]Based on petrographic observations of the Malakand graphite, the order of the appearance of various phases is biotite- amphibole pair, plagioclase and alkali-feldspar, muscovite, and calcite, respectively. [3]The geochemistry of granite also indicates the dominant control of feldspar fractionation on the liquidus together with the fractionation of the ferromagnesian minerals. [4]Biotite, amphibole, Iron-titanium oxides and sphene represent the earliest association on the liquidus, while feldspars followed this assemblage. [5]Considering the granite crystallization under a PH20 of 5 kb (cf.Fig.4), majority of the granite analyses show a temperature range of 80850°C on Ab-An-Or (normative) plot of Yoder et al., (1957; not represented).

[6]This temperature range can be related to feldspar crystallization. [7]Muscovite seems to be appeared on the liquidus at temperature lower than that suggested for feldspar. [8]As suggested earlier that biotite-amphibole pair appeared on liquidus before the appearance of feldspar. [9]Thus, a temperature greater than 85°C under similar PH20 is suggested for the ferromagnesian minerals.

[10]The association of primary sphene with amphibole and biotite is consistent with this interpretation (cf. Hamidullah, 1983, p. 98). [11]The maximum temperature under a PH20 of 5 kb for the appearance of two feldspars (albite and orthoclase) in albite orthoclase system is about 700°C (Yoder et al., 1957).

[12]However, albite, orthoclase have not crystallized simultaneously in the Malakand granite but the presence of perthite indicates that exsolution of plagioclase and K-feldspar has occurred (Jabeen et al., 1985) probably at a temperature below the solidus in albite-orthoclase system. [13]A temperature of 650°C and a PH20 of 5kb are suggested for such phenomenon in the Malakand granite (cf. Bowen and Tuttle, 1950).

[14]Quartz and calcite are interstitial to feldspar in Malakand granite and are of magmatic origin. [15]Therefore, their crystallization may have occurred at a temperature higher than 650°C (i.e., feldspar exsolution temperature). [16]Apatite is generally associated with plagioclase. [17]Therefore, P-T condition similar to those suggested for the crystallization of plagioclase are also proposed for the development of apatite.

[18]The Malakand gneisses also represent highly variable lithology. [19]The normal granite gneiss of Jolagram, and Jalal Kot corresponds to Malakand granite on the basis of their chemistry, and considered to be of igneous parentage and are genetically related to the Malakand granite. [20]On the other hand, the silica- rich granite gneiss of Dabrai and siliceous gneiss of Jolagram, and near tunnel entrance (cf. Map 1) contain much higher quartz content. [21]Therefore these gneisses may be metasedimentary in nature, originally containing a large proportion of quartz with some feldspar and ferromagnesian minerals or the products of partial melts from a deep source. [22]Except the garnet, developed locally in the vicinity of granitic veins, the gneissose rocks have generally passed through the biotite zone of green schist facies metamorphism. [23]For example, brown biotite has developed at the expense of muscovite and opaque minerals (Jabeen et al., 1985).

[24]The petrography and field relationship show that the metasediments associated with Malakand granite, gneiss complex have passed through several episodes of regional and contact metamorphism. [25]Rocks exposed south of the Malakand proper indicate a general northward increase in the grade of metamorphism. [26]The dominant mineral assemblage near Malakand road tunnel is that of the biotite zone of the green schist facies (Turner and Verhogen, 1960), while graphite schist near Malakand proper indicate the prevalence of amphibolite facies conditions (see Miyashiro, 1973).

[27]Garnet is generally restricted to the contact of metasediments with Malakand granite (e.g., Malakand proper, Tor Mor Rest House block) although occasionally it has been noticed at considerable distance from the granite- metasediment contact, i.e., 3-4 km on road side, south of Malakand proper, (cf.Jabeen et al., 1985).

[28]The presence of garnet in the metasediments indicates that the metamorphism in garnet zone of the amphibolite facies has occurred and was probably related to the thermal effects of the emplacement of the granitic magma, however, compositional factors controlling the development of garnet cannot also be ruled out and needs further investigation. [29]The development of garnet in the gneissose rocks in the vicinity of granitic veins is consistent with these interpretations.

[30]In chlorite-epidote schist near Malakand road tunnel chlorite, cross cutting the general fabric of the rock occurs in equilibrium with epidote replacing amphibole. [31]This reflects the prevalence of green schist facies conditions. [32]Moreover, biotite has developed at the expense of chlorite which indicate a return to relatively higher metamorphic grade. [33]All these features point to highly variable metamorphic conditions locally, and can be related to the prevalence of regional metamorphism and increase of temperature associated with the emplacement of granite.

[34]The present investigation shows that both the Malakand gneisses and metasediments have evolved through similar metamorphic conditions at least after the emplacement of gneisses.

[35]The Malakand granite has Rb/Sr ratios varying from 0.25-0.62. [36]The minimum limit of this range is in accordance with that of the crustal values i.e., 0.25. [37]The K/Rb ratio of the Malakand granite c. 123-219 is however, considerably lower than that proposed for crustal derived rocks (see Gunn, 1965). [38]The Malakand granite is sufficiently rich in plagioclase and can be classified as Na-rich granite (cf. Fig.3e). [39]Therefore, the lower K/Rb ratio can be related to its richness in Na20, the calc-alkaline character and probably a high degree of fractionation (see Abbot, 1967).

[40]The Malakand granite is considered to be a part of the alkaline igneous province of Peshawar plain (Kempe, 1973; Kempe and Jan, 1979; Jan et al., 1981). [41]Majority of the rock of alkaline igneous province are alkaline in character. [42]The Malakand granite differs from most of the granitic members of the alkaline province on the basis of its lower alkalinity.

[43]In addition, Kempe (1973) has determined a 45 m.a. age for the granitic rocks of the Warsak alkaline complex and Ambela granitic complex. [44]On the other hand Moluski and Matte (1984) have attributed an age of 23 + 2 m.a. to the Malakand granite, on the basis of 40Ar/39Ar technique and using biotite separates[45]. However, similar age (23 m.a.) has been determined for the Malakand granite using zircon fission track data by Zeitler et al., (1982) and thus both these dates may be representing cooling and uplift ages.

[46]The lack of deformation in the Malakand granite, however, strongly supports the view of this intrusion being younger than the rocks of the alkaline igneous province of Peshawar plain. [47]In addition, the calc-alkaline character of the Malakand granite also supports the view that there is not any genetic relationship between this granite and the rocks of the alkaline igneous province of the Peshawar plain.

CONCLUSIONS

[48]1. The Malakand granite intruding metasediments of probable Precambrian age is calc-alkaline in character.

[49]2. In the Malakand granite, biotite, amphibole, sphene and iron-titanium oxides have crystallized at a temperature 875°C and PH20 of about 5 kb.

[50]3. Feldspars developed at a temperature of 800-850°C and PHIO of 5 kb.

[51]4. On the basis of textural relationships with various phases, a temperature 650°C and PH20 5 kb are suggested for the crystallization of quartz and calcite.

[52]5. Malakand gneisses and metasediments have been generally metamorphosed upto the upper limits of the green schist facies. [53]Thermal metamorphism upto the garnet zone of amphibolite facies has been however, noticed both in metasediments and gneisses near the contact of the Malakand granite.

[54]6. Among the three types of gneisses, the normal granite gneiss seems to be genetically related to the Malakand granite. [55]In addition, on the basis of certain geochemical features and age relationships, the Malakand granite does not seem to be genetically related to the alkaline igneous complex of the Peshawar plain.

PAK-23: Petrology of the Bibai volcanics, NE Baluchistan

[1]The Bibai rocks indicate significant volcanic activity in the northeastern Baluchistan towards the close of the Cretaceous (Campanian to Maestrichtian). [2]Initially during Campanian the volcanic activity was submarine (pillow structure, interfingering with marine Parh limestone), followed by a subaerial phase (volcanic ash containing lapilli etc.) during the Maestrichtian. [3]Similar events appear to have taken place in southern Baluchistan (Bela area) during the late Cretaceous and there is considerable analogy between the Bibai volcanics and the Porali volcanics of the Bela area (Allemann, 1979; HSC, 1960).

[4]The great thickness and exceptional roundness of the Bibai volcanic conglomerates suggest presence of a large volcanic island.

[5]This is yet another evidence for the presence of one or more island arcs which came into existence during late Cretaceous along the margins of the northward drifting components of the dismembered Gondwana-land (Takin, 1972; Gansser, 1971; DeJong and Subhani, 1979). [6]By the Maestrichtian most of the older part of the Tethys lying between Gondwanaland and Eurasia had been consumed and its remnants now contained chipped off fragments of Gondwanaland (microcontinents) and one or more island arcs separated by marginal seas (Stocklin, 1974; Powell, 1979).

[7]This remnant of the Tethys has also been referred to as the Zagros - Chitral convergence zone by Powell. [8]By the late Maestrichtian the northward drifting components of Gondwanaland (Arabia and India) had collided with this zone resulting in the obduction of ophiolitic masses (Oman, Bela, Zhob, etc.) and formation of wide zones of extensive thrust slices such as those seen near Kach.

[9]The northward tapering structure of the Bibai volcanics near Kach indicates that the Bibai nappe was initially located on the northern slopes of the volcanic island chain. [10]South of Kach there is no sign or trace of any ancient source of volcanic activity. [11]On the contrary the area south of Kach comprises the autochthonous zone. [12]It is therefore inferred that the Bibai nappe has undergone considerable southward tectonic transport, probably of the order of several tens of kilometres.

[13]The Zhob valley obducted masses of philites emplaced during the late Palaeocene (Allemann, 1979), lie only at a short distance northeast of the Bibai nappe. [14]The Bibai nappe and the Zhob ophiolites are both located in the same wide belt of imbricate structure (referred to as Balla Dhor-Zhob-Kurram ophiolite belt and scuppen zone by Kazmi, 1982) that runs through north- eastern Baluchistan. [15]It may be therefore inferred that this nappe may have formed at the same time or slightly before the emplacement of the Zhob ophiolites. [16]It is likely that the Zhob ophiolites may have initially constituted the "foundation" of the Bibai island arc and part of the adjacent oceanic crust.

PAK-24: Ultramafic and mafic rocks of Thurly Gah and their relationship to the Chilas complex, N. Pakistan

[1]As in the Chilas area, ultramafic and related rocks are emplaced in noritic rocks in Thurly Gah area. [2]Our study leads to the following results which are also applicable to the Chilas complex as a whole.

[3]1) The petrological division of the Chilas complex into two associations, main noritic association and a subordinate association of the ultramafic and mafic rocks (Jan et al., 1984; Asif Khan et al., in prep.) is supported by field and petrographic characteristics (Table 3).

[4]2) The ultramafic and associated mafic rocks are emplaced in the form of isolated, lensoid bodies rather than, as found in the type stratiform complexes, in continuous stratigraphic horizons.

[5]3) Inspite of an overall intrusive mode of emplacement of the ultramafic and associated mafic rocks, there is a strong concordance in the planar structures (such as foliation, layering, contacts) of the two associations. [6]Parallelism of layering suggests that the magma of the younger group of rocks was emplaced before tilting of the main norites.

[7]4) Both the associations are characterized by the presence of minor discordant bodies, grossly within their respective compositional ranges. [8]These bodies probably represent subsolidus mobility of the magmatic liquids or crystal mushes, being squeezed out into fractures and other weak zones produced by the burden of overlying magmatic rocks and other crustal material. [9]But some may also have developed as a consequence of slumping. [10]The abundance of orthopyroxene and amphibole in the discordant ultramafic bodies, and the frequency of amphibole in the noritic dykes suggest a major contribution of the intercumulus material in these discordant bodies.

[11]Similar discordant bodies in other stratiform intrusions are also considered to be contemporaneous to layered cumulates (Stillwater Complex, Raedak and McCallum, 1984; Duke of Island Complex, Irvine, 1974).

[12]5) The pervasiveness of the tectonic foliation through the rocks of both the associations suggests that the emplacement

of the ultramafic and associated mafic rocks predated all the deformational events in the complex.

[13]It is hoped that the field and petrographic aspects outlined here will provide a better understanding of the relationships amongst the constituent rocks of the Chilas complex. [14]However, in the absence of detailed isotopic and geochemical work it is difficult to sort precise genetic inter-relationship between the two associations. [15]Jan et al., (1984) invoked chemical zoning of the magma chamber into a picritic basal part and a noritic main part, followed by intrusion of the picritic basal liquid into crystallized norites. [16]Naslund (1983) has also suggested chemical zoning to have operated in the case of the Skaergaard intrusion. [17]Nevertheless, an attempt can be made here to outline a model for the magmatic evolution of the Chilas complex (Fig.11).

[18]Taking into consideration the volume proportions and the field and petrographic aspects (outlined in this paper and in that of Jan et al., 1984), we suggest that the ultramafic and associated mafic rocks may represent isolated pulses of a relatively primitive (? picritic) magma emplaced at the crystallizing floor of a previously existing magma reservoir corresponding to the main noritic association of the Chilas complex. [19]This sort of replenishment of the cumulusly crystallizing magma chambers by later pulses of relatively primitive magma are well documented in recent literature from the stratiform complexes (Rhum ultramafic complex, N.W. Scotland, Huppert and Sparks, 1980; Hettash Intrusion, Labrador, Berg, 1980), and have been successfully simulated in laboratory experiments (Huppert and Sparks, 1980, 1984). [20]There is, however, a major difference in these models and the one being suggested for the Chilas complex. [21]Whereas in both Hettash and Rhum intrusions it is considered that replenishing phases of a relatively primitive magma (although keeping their entities during most of the course of crystallization) ultimately merged with the host magmas, in the Chilas complex, there are no evidences of such mixing. [22]On the contrary, even the most differentiated members of the association of the ultramafic and mafic rocks are substantially different from the main noritic hosts (Asif Khan, unpublished data). [23]In the light of these considerations it is suggested that the two associations of the Chilas complex crystallized simultaneously but from magmas of substantially different compositional and rheological properties, thus hindering any mixing or hybridization.

PAK-25: Mineralogy of the Blueschist facies metagraywacke from the Shergarh Sar area, Allai Kohistan, N. Pakistan

[1]The petrographic and mineral chemistry data, discussed in the previous sections, is inadequate for a precise estimation of the P-T conditions prevailing during the metamorphism of the studied rocks. [2]Still it is helpful in pointing out some vaguely defined limits based on the following reaction boundaries (see Fig.14, Jan, 1985) relevant to the Allai Kohistan paragenesis: [...].

[3]Presence of glaucophane, epidote, quartz, plagioclase, calcite, and complete absence of pumpellyite, prehnite, paragonite, aragonite and jadeite in the studied paragenesis suggest a temperature range of about 400-450°C at 7-8 kbar pressure. [4]The (Na)M vs AlVi of the glaucophane also suggests a pressure of about 7 kbar (cf. Brown, 1977). [5]The average Si contents (7.00) of phengite analyses in Table 2, according to the method of Velde (1965), further confirm the pressure values calculated by the first two methods. [6]Due to the complete absence of lawsonite and barroisite, the temperature range of Allai paragenesis is restricted compared to that of the Ladakh paragenesis (Compare Jan, 1985).

[7]The absence of the barroisite and calcic amphibole development either in the successive zones around the sodic amphibole or as distinct grains, opposes any retrogression as found in eastern Ladakh, or oscillatory transition in metamorphic conditions as noted in Shangla. [8]One possibility is that these rocks were uplifted at a very fast rate.

PAK-26: Shear waves provide an extra control on seismic interpretations

[1]The Vs-distribution in the area (Fig.4) shows clearly the lateral as well as vertical velocity variations. [2]The continuous increase of velocity with depth in vertical column is attributed to the closing of cracks in rocks due to overburden pressure (Toksoz, et al., 1976), whereas the lateral change is associated with varied lithology. [3]Over pyroxene-granulites of the central belt Vs appears high, but at 5 km to the south (across Scourie) it decreases rapidly in retrogressed schists and then progressively reaches a minimum over granites and pegmatites (Ben Stack Line). [4]Further north, it rises and gives almost uniform estimates in quartz-feldspathic gneisses, relatively lower than those pyroxene-granulites. [5]This correlation between Vs-distribution and lithology shows the sensitivity of shear waves to compositional changes. [6]If this distribution is compared with Vp model of the area (Fig.5) designed from P-arrivals data (LUST) using ray tracing (Hall, 1978), it becomes clear that the general pattern in both cases is almost similar except for the following differences:

[7]i) Vs decreases more gently than Vp in retrogressed equivalents of pyroxene-granulites. [8]ii) Vs does not show a high velocity spike as exposed by Vp near Loch Inchard at a depth of 1 km.

[9]It is obvious that Vp spiking is caused by a local compositional change in more acidic environments of quartz-feldspathic gneisses, this could be due to pyroxene-granulites or amphibolites. [10]Because both being of high velocity can produce a velocity jump. [11]The acceptable candidate would be that which satisfies conditions imposed by Vp and Vs, i.e., Vp should be much higher than that of quartz- feldspathic gneisses but Vs similar. [12]For that finding the problem is treated quantitatively.

[13]If rocks are defined, by a five mineral assemblage (quartz, plagioclase, k- feldspar, amphibole and pyroxene), and effective velocities (Vp, Vs) for these minerals are known, then the aggregate velocities (Vp, Vs) can be estimated for different rocks on the basis of Birch (1943) model given below.

[14]V = 1/X Where Xi is the volume percentage of ith mineral occupying the rock, and Vi is the effective velocity in that mineral. [15]With the use of estimated effective velocities (Hall and Al-Haddad, 1979; Ali, 1983) and mean composition in the above mentioned treatment the aggregate velocities for different lithologies are given in Table-1 .

[16]It can be noticed from Table-1 that Vp for amphibolitic composition is much higher than that of quartz-feldspathic gneisses but Vs is similar. [17]Pyroxene granulites, on the other hand, offer higher Vp as well as Vs. [18]In the view of this estimation the most probable explanation for Vp-spike in the zone of almost flat Vs is the existence of concealed amphibolite body (not pyroxene- granulites) below the acidic gneisses which may have a link with the exposed amphibolite complex. [19]This confirms Hall's (1978) view that there is no evidence for shallow (upto 2 km depth) existence of a substantial body of pyroxene-granulites under the northern belt. [20]It is interesting to note that Vp and Vs for retrogressed rocks are very similar to those of acidic gneisses (Table-1). [21]This suggests that if retrogressed rocks underlie the gneisses the detection of the interface would not be possible by seismic methods.

[22]As far as retrogressed equivalents of pyroxene-granulites in the central belt are concerned, it appears from Table-1 that (in reconstitution of minerals in retrogressive metamorphism) the reduction in velocities (Vp, Vs) are due to increased contents of quartz and amphibole at the expense of pyroxene. [23]The Vp/Vs distribution (Fig.6) obtained from the combination of Vp and Vs models gives a resolved picture of the area, the dominant lateral and vertical variational trends in central and northern belts, and shows a progressive lateral decrease (north wards) in these rocks. [24]If replace-

ment of pyroxene by amphibole is supposed to be the only mineralogic change in retrogression then theoretically Vp/Vs should give a gradual increase. [25]But the observation is opposite. [26]This suggests that quartz would be the other variable whose extremely low Vp/Vs (1.48) overshadows the effect of amphibole increase. [27]The situation is clarified in Table-1, i.e., the increased volume percentage of amphibole when counteracted by the addition of similar amounts of quart in the composition of retrogressed rocks, the Vp/Vs is decreased. [28]The small interchange in feldspars as compared to feldspars component of pyroxene- granulites causes negligible effect in Vp/Vs. [29]It is, therefore, inferred that retrogressed rocks are subjected to gradual increase of quartz alongwith amphibole (northwards) at the expense of pyroxene content.

CONCLUSIONS

[30]1. The correlation between lateral lithological changes and shear wave velocities suggests a potential of shear waves to enhance geological modelling. [31]2. Near Loch Inchard, the detected Vp-spike is probably due to a concealed amphibolite mass instead of pyroxene-granulite masses. [32]3. The progressive decrease in Vp/Vs (northwards) in retrogressed rocks seems to be the result of an increased component of quartz in retrogression. [33]4. The possibility of shallow existence of pyroxene-granulites under quartz- feldspathic gneisses of the northern belt does not apply. [34]5. If retrogressed rocks exist under quartz-feldspathic gneisses, the detection of the interface, seismically, is not possible.

PAK-27: Tectonic significance of mylonites from Mingora, Swat

[1]Mylonites are widely distribution in orogenic belts. [2]These occur as narrow zones of intense shearing, either localized on fault planes, or dispersed in crystalline basements. [3]At temperatures of the greenschist facies or beyond, deformation of crystalline rocks may proceed largely by the formation of narrow planar shear zones (Mitra, 1978). [4]Such mylonites are common in the Mingora gneisses. [5]The mylonites at the base of the gneisses, however, could not have been formed in this manner. [6]The thickness (over a hundred metres) and the unrelated rocks below indicate their formation at the base of a large thrust sheet. [7]This thrust may have been formed in response to the obduction of the Kohistan island arc (Fig.3). [8]The presence of a northward plunging lineation in the rocks below the suture and the regional northward dip of the major structures (Malinconico, 1982) suggests southward thrusting of the Swat gneisses, possibly over the Ambela granite.

[9]It is further proposed that the term "Manglaur schist" be formally abandoned and the various lithologies referred to individually, until more data becomes available for proper nomenclature. [10]The general recrystallization of mylonites observed in the study area suggests that other major shears in the region may be similarly obscured.

CONCLUSIONS

[11]Schists, marbles, amphibolites, and underlying gneisses of lower Swat and Buner constitute a crystalline thrust sheet of the Indian plate. [12]This unit moved southwards in response to the obduction of the Kohistan island arc, on a thrust plane now exposed at the base of the Swat gneisses as a zone of recrystallized mylonites. [13]These mylonites have smaller thrust slices of rapakivi granites, sillimanite gneisses, marbles, and schists. [14]The entire unit is tightly folded, and has been considered to be a metasedimentary sequence into which the Swat gneisses have been intruded. [15]Infolding and thrusting account for the intercalation of the gneisses and schists which have been previously mistaken for intrusions or xenoliths. [16]The recrystallisation of the mylonites explains their late recognition.

PAK-28: Major and trace element variations in the lavas of Shergarh Sar area and their significance with respect to the Kohistan Tectonic anomaly

[1]The major and trace element constraints of the studied lavas are employed in the problem of identifying their primary/derivative character and more use- fully elucidated as tectonic fingerprints in revealing the type of environment at the time of their generation. [2]Green (1976) and Frey et al., (1978) suggested a few general criteria to check whether basalts occurring in an area represent primary melts from the upper mantle or liquids modified by fractionation (derivative liquids). [3]These are (a) the presence of the spinel lherzolite xenoliths (b) Mg-values, and (c) compatible trace element concentrations. [4]Occurrence of spinel lherzolite xenoliths in basalts suggests that magma has ascended from depths 30 km without crystal fractionation. [5]The absence of such xenoliths in lavas from the studied suite make their primary status doubtful at first instance.

[6]Mg-value (100 Mg/(Mg + Fe + 2)) within the range of 88-89 are suggested for best least refractory upper mantle peridotite parent for the generation of basaltic liquids (Frey et al., 1978). [7]Magma of basaltic composition derived from such a source peridotite must have Mg-values of 68-75 for upto about 30 percent melting (using KD(Ol/Liq) = 0-3, Roeder and Emslie, 1970). [8]Applying this criterion to the compositions in Table 2, it is clear that Mg-values are varying between 39-67 and all the analyses are regarded as fractionated liquids, as also suggested by the absence of spinel lherzolite.

[9]The concentrations of Ni and Cr within the analysed samples are well below the reported range of these elements in basalts derivative from mantle peridotite (Ni 250-300 PPM and Cr 500-600 PPM, Green, 1976). [10]Frey et al., (1978) in their partial melting model of lherzolite reported a Co range of 27-80 PPM in the primary basalts. [11]The Co abundances in Table 4 lie within this range. [12]However, it is not appropriate to assume on the basis of only Co abundances that these lavas are primary partial melts from the upper mantle peridotite while the remaining petrochemical indices strongly oppose such a relationship.

[13]Close correspondence between the average analysis of tholeiite from the studied area and tholeiite from the island arc type environments is further displayed graphically with the help of selected discriminative type two-dimensional and triangular plots in Fig.10 to 12 (after Pearce, 1975; and Mullen, 1983). [14]Concentration of the composition points of lavas from the Shergarh Sar area within the areas outlined for island arc tholeiites favours their production in an island arc type environment.

[15]Prevalence of the island arc structure(s) in the Tethys ocean before the collision between the Indo-Pakistan and Asian Plates (Cretaceous) is already interpreted fully in accordance with the proposed plate tectonic models of N Himalaya (Tahirkheli, et al., 1979; Klootwijk et al., 1979; Majid and Paracha, 1980; Jan, 1980; Majid, et al., 1981; Jan and Asif, 1983; Virdi, 1981; Andrews, Speed and Brookfield, 1982, Coward et al., 1982; Bard, 1983). [16]The petrochemistry of lavas from the studied suit provides a chemical support for such a supposition.

PAK-29: Coronites from the Chilas and Jijal-Patan complexes of Kohistan

[1]On the basis of physical conditions the coronas in the Jijal-Patan and Chilas complexes can be divided into three categories: 1) High P-high T, Ps > PH2O; 2) Medium P-high T, Ps > to PH2O; and 3) Medium to low P-low T, Ps = PH20. [2]The first one occurs locally in the Jijal-Patan complex, the latter two in the Chilas complex.

[3]In the Jijal-Patan complex, orthopyroxene and plagioclase could not stably coexist under the prevailing conditions and reacted to produce garnet + clinopyroxene coronas. [4]In most rocks the reaction reached completion and either orthopyroxene (more readily olivine in the Si-poor rocks) or, rarely, plagioclase was totally consumed, depending upon the modal ratio of the two phases.

[5]The Jijal assemblages are typical of high-P granulite facies of Green and Ringwood (1967).

[6]Garnet-clinopyroxene geothermometry (Ellis and Green, 1979; Saxena, 1979; Ganguly, 1979; Wells, 1979) and other considerations suggest that the Alpurai (Jan, unpublished data) and Jijal-Patan granulites were metamorphosed at about 850°C and 12-14 kbar (cf. Jan and Howie, 1981b; Bard, 1983). [7]These rocks occur in the north of MMT (suture zone) and their high-P metamorphism may be due to subduction/burial to depth of 40 km along the suture zone. [8]During uplift the rocks had access to water and a number of lower grade minerals, especially hornblende, epidote and paragonite, developed.

[9]The medium P-high T coronas in the Chilas complex apparently developed under such conditions that highly calcic plagioclase (bytownite-anorthite) could no more coexist stably with mafic minerals. [10]The plagioclase reacted with olivine to produce orthopyroxene-clinopyroxene/hornblende + spinel coronas, with orthopyroxene to give clinopyroxene/hornblende + spinel coronas, and with clinopyroxene to form hornblende + spinel coronas. [11]Such coronas have been attributed to diffusion during slow cooling after the solidification of rocks or to metamorphism (Mason, 1969; Sapountzis, 1975). [12]Magmatic processes, such as the one proposed by Rai (1979) for Kargil coronites, cannot be applied to the Chilas rocks. [13]In addition to some evidence we have found for diffusion, it will be difficult to produce the observed variety in the mineral paragenesis of the Chilas rocks by a late magmatic process. [14]The formation of amphibole or clino-pyroxene in different coronas may be a function of variation in the water vapour pressure.

[15]Griffin and Heier (1973) suggested that clinopyroxene + spinel coronas form either due to lowering of temperature (during uplift) from initially higher magmatic temperatures, or to an increase of pressure. [16]Increase in pressure may be brought about by shearing, subduction or sinking under a growing pile of rocks. [17]Various methods of geothermometry (Perchuk, 1969; Wood and Banno, 1973; Obata, 1976; Wells, 1979; Dahl, 1980) suggest that the Chilas coronites finally equilibrated under pyroxene granulite facies at 750-850C. [18]These estimates are based on the assumption that equilibrium was maintained during the growth of the coronas. [19]For details of symplectite- forming reactions, see Mongkol and Ashworth, 1983). [20]The instability of very calcic plagioclase with orthopyroxene or olivine to yield two pyroxenes + spinel, and the absence of garnet suggest that the operating pressure was below 7 kbar at these temperatures (Kushiro and Yoder, 1966; Green and Ringwood, 1967; Obata, 1976). [21]However, the pressure was not high enough to promote such a reaction between a more sodic plagioclase (medium labradorite to andesine) and orthopyroxene in the more abundant norites of the Chilas complex. [22]Bard (1983) suggested that the Chilas coronites formed under pyroxene granulite facies conditions and our data do not contradict him, although the possibility of their development during uplift cannot be ruled out.

[23]The moderate to low P-low T coronas producing amphibole and epidote at the cost of pyroxene and plagioclase are clearly the result of retrograde processes. [24]In the presence of water along the plagioclase-pyroxene interface, they were produced during the uplift of the pyroxene granulites to higher levels and are suggestive of epidote amphibolite facies conditions. [25]The reaction [...] has affected a few rocks more extensively than the grain boundaries, thus bridging the gap to epidote amphibolites.

PAK-30: Petrochemistry of the rocks from Babaji area, a part of the Ambela Granitic complex, Buner Northern Pakistan

[1]The major element oxides vs. SiO variation diagrams for the rocks of Babaji area (Fig.5) exhibit a transition from syenites to granites. [2]The compositional discontinuity between SiO = 62-65% and 68-73% is probably due to an incomplete sampling. [3]There is decrease of Al2O3, FeO + Fe2O3, Na2O, K2O and CaO with increase of SiO2, signifying their genetic relationship. [4]Similar behaviour is distinct on the plot of normative CIPW composition of the studied rocks in Q-Ab-Or system (Fig 6). [5]This suggests the control of their composition by fractional crystallization. [6]The analyses project along the alkali feldspar join and terminate near the ternary minimum. [7]However. [8]the normative composition of samples AG1 and AG5, due to a considerable alteration of feldspar, plot away from the ternary minimum towards the quartz-rich side of the ternary system.

[9]The geochemical parameters of the Babaji rocks suggest that they may represent a typical extensional or release-type of plutonic suite, associated with rifting. [10]This extensional type of environment probably was produced during 50-55my ago, when the rapid rate of spreading of Indian mass was suddenly subsided due to its initial contact with Eurasia (Powell and Conaghan, 1973, 1975). [11]Age evidence of 50my for Koga Syenites (Kempe, 1973) is in accordance with palaeomagnetic data.

[12]As alkaline rocks the world over are mostly associated with rifting (cf.Sorensen, 1974; Smith et al., 1977; Bailey, 1978; Tayler et al., 1980; Radian et al., 1981), the Babaji rocks are also considered to have originated in rift- related environments. [13]They might have been derived from an (alkaline) basaltic or trachytic magma (cf. Kempe, 1973), however, not enough research has been carried out in this regard.